

UNCLASSIFIED

AD NUMBER
AD472155
NEW LIMITATION CHANGE
TO Approved for public release, distribution unlimited
FROM Distribution authorized to U.S. Gov't. agencies and their contractors; Administrative/Operational Use; JUL 1965. Other requests shall be referred to Naval Training Device Center, Orlando, FL.
AUTHORITY
USNTDC ltr dtd 19 Oct 1967

THIS PAGE IS UNCLASSIFIED

SECURITY

MARKING

The classified or limited status of this report applies to each page, unless otherwise marked.

Separate page printouts MUST be marked accordingly.

THIS DOCUMENT CONTAINS INFORMATION AFFECTING THE NATIONAL DEFENSE OF THE UNITED STATES WITHIN THE MEANING OF THE ESPIONAGE LAWS, TITLE 18, U.S.C., SECTIONS 793 AND 794. THE TRANSMISSION OR THE REVELATION OF ITS CONTENTS IN ANY MANNER TO AN UNAUTHORIZED PERSON IS PROHIBITED BY LAW.

NOTICE: When government or other drawings, specifications or other data are used for any purpose other than in connection with a definitely related government procurement operation, the U. S. Government thereby incurs no responsibility, nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use or sell any patented invention that may in any way be related thereto.

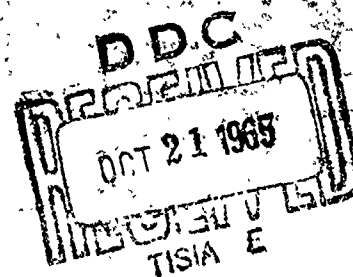
Technical Report: NAVTRADEXCEN 1218-4

GUIDELINES FOR TRAINING SITUATION ANALYSIS (TSA)

Andrew P. Chenzoff
John D. Folley, Jr.

Applied Science Associates, Inc.
Valencia, Pennsylvania
Contract No. N61339-1218

July 1965



ABSTRACT

GUIDELINES FOR TRAINING SITUATION ANALYSIS (TSA)

These guidelines represent a textbook for instruction in three phases of Training Situation Analysis (TSA), a standardized procedure, developed by NTDC, for systematically gathering and interpreting the information which is relevant to the planning of training and training devices.

Three phases of TSA are described in detail: System Familiarization, Task Analysis Method (TAM) and Training Analysis Procedure (TAP). Systems Familiarization provides an orientation to the training problem, the system structure and flow, and the equipment. Task Analysis Method produces a set of task descriptions containing the information necessary for making training device decisions. Training Analysis Procedure produces a ranking of tasks based upon the potential benefit to system performance as a result of training and the cost of that training. Recommendations for the conduct of these three phases and suggested working forms are presented.

Qualified requesters may obtain copies of this report direct from DDC.

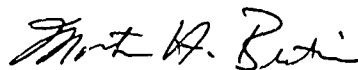
Reproduction of this publication in whole or in part is permitted for any purpose of the United States Government.

F O R E W O R D

This handbook represents a major step in the formulation of a quantified and systematic approach to developing training devices. It covers the basic analytic features of the Training Situation Analysis (TSA) and in particular the human participation in the operational system and the effects of training on operational performance. It provides a means for gathering and handling only the information needed for making training decisions and suggests a means, though not a format, for "turning the corner" into a description of functional training requirements.

The Training Analysis Method (TAM) and Training Analysis Procedure (TAP) covered were developed by two research groups. The initial handbook on TAP* was published separately and is reprinted here with minor changes designed to better accommodate the TAM approach. Limited application of the methodology has been undertaken and the results indicate considerable potential for future use. The development of a single document to guide the analyst through the maze of quantification is convenient, allowing more time and a more secure base for translating the data and findings into functional characteristics. As a tool, its utility will be directly proportional to the experience, skill, and competence of its user, and it in no way substitutes for the talents of the training specialist.

These guidelines provide a framework within which TSA Teams may operate more effectively. The design and format must be tested over time and in application to various systems and problems. Hopefully, the insights gained during use will result in whatever changes are indicated. In this way it should be possible to incorporate the knowledge of each TSA Team for the benefit of future groups and projects.



MORTON A. BERTIN, Ph.D.
Scientific Officer
U. S. Naval Training Device Center

*NAVTRADEVCCEN 1169-2, Training Analysis Procedure (TAP), Volume 2, Handbook for Application, January 1964.

TABLE OF CONTENTS

	<u>Page</u>
SECTION I TRAINING SITUATION ANALYSIS (TSA)	1
A. Introduction	1
1. Historical Perspective	2
2. Philosophy of TSA	4
B. General Description	5
C. Current Status	7
SECTION II SYSTEM FAMILIARIZATION	9
A. Classes of Data	9
1. The Problem	9
2. The System	10
B. Sources of Data	11
C. The Operational Sequence Diagram	14
SECTION III GUIDELINES FOR TASK ANALYSIS METHOD (TAM) . . .	18
A. Introduction to TAM	18
1. The Nature of Task Analysis	19
2. The Nature of the Task Analyst	21
3. Some Basic Definitions	24
4. Phases of Task Analysis	25
B. Development of System Block Analysis	27
C. Development of Task-Time Charts	29
1. Task Identification	30
2. Determine Typical Total Block Time	33
3. Determine Typical Duration and Coordination .	34

Table of Contents (continued)

	<u>Page</u>
4. Determine Adverse Conditions that Affect a Given Time Period	38
D. Preparing Functional Task Descriptions	44
1. Determine Time Performance Requirement and Typical Task Time	46
2. Identify Activities in the Task and Show Their Time Relationships	49
3. Determine the Percentage of Attention Devoted to Each Activity	56
4. Identify Contingencies	58
5. Identify Adverse Conditions that Apply Only to One Task	63
E. Preparing Behavioral Details Descriptions	64
1. Procedure Following	66
2. Continuous Perceptual-Motor Activity	68
3. Monitoring	69
4. Communicating	70
5. Decision Making and Problem Solving	70
F. Recapitulation and a Look Foreward	72
SECTION IV GUIDELINES FOR TRAINING ANALYSIS PROCEDURE (TAP).	74
A. Introduction to TAP	74
1. A Definition of TAP	74
2. The Term "System" as Used in TAP	74
3. Task Criticality	75
4. Performance Estimation	75

Table of Contents (continued)

	<u>Page</u>
B. The Selection of Tasks for the Training Environment .	79
1. The Effects of Training	79
2. The Effects of Cost on the Selection of Tasks for Training	90
3. The FOM/COST Ratio - A Summary of TAP Procedures	93
C. Diagramming the Network and Obtaining TAP Data . . .	94
1. The TAP Network	94
2. Data Collection	99
D. Rate Systems - Procedures	108
1. Networks	110
2. Task Table	113
3. Cost Table	118
4. Iteration Table	124
5. Table of Results	131
E. Fixed Sequence Systems - Procedures	135
1. Network	135
2. Task Table	137
3. Cost Table	144
4. Iteration Table	151
5. Table of Results	164
F. Mixed Systems - Procedures	167
1. Linked Fixed Sequences	168
2. Tasks Considered in Computing the Rate Ratio . .	170
3. Repetitive Sequences of Tasks	171

NAVTRADEVCEEN 1218-4

Table of Contents (continued)

	<u>Page</u>
4. Negative FOM's	173
APPENDIX A RATE SYSTEM PROCEDURES CHECKLIST	176
APPENDIX B FIXED SEQUENCE SYSTEM PROCEDURES CHECKLIST	180
APPENDIX C MIXED SYSTEM PROCEDURES CHECKLIST	184
APPENDIX D TAP GLOSSARY	189

LIST OF TABLES

<u>Table</u>		<u>Page</u>
1	Stages in Task Analysis and Kind of Data Obtained in Each Stage	27
2	Corridor Penetration System - Task Table	118
3	Corridor Penetration System - Cost Table (One Installation).	124
4	Corridor Penetration System - Iteration Table	134
5	Task Table - Tracer System	138
6	Cost Table - Tracer System	149
7	Tracer System Iteration Table	166

LIST OF ILLUSTRATIONS

<u>Figure</u>		<u>Page</u>
1	The Major Stages in Training Situation Analysis . .	6
2	Illustration of Operational Sequence Diagram Symbols and Format	16
3	Part of a System Block Analysis	29
4	Task-Time Chart (Front)	31
5	Task-Time Chart (Back)	41
6	Functional Task Description Form	45
7	Categories for Focusing Questions about Contingencies	63
8	Behavioral Details Description Form	65
9	Multipath Fixed Sequence System	94
10	Complex System Network.	98
11	Corridor Penetration System Network	112
12	Corridor Penetration System - System Improvement as a Function of Cost	133
13	Tracer System Network	136
14	Multiple Networks	153
15	Sample Multipath System	158
16	Tracer System - System Improvement as a Function of Cost	165
17	Network - Paths - Computation of "K"	166

SECTION I

TRAINING SITUATION ANALYSIS (TSA)

A. Introduction

A difficult and persistent problem facing the U. S. Naval Training Device Center, and other military installations concerned with training, has to do with the planning of training and training devices during the early stages of design and development of complex man-machine systems. Ideally, the training programs and training devices should become available before the systems for which they were developed become operational. Since a considerable amount of time is required to implement a training program and to produce and distribute training devices, the planning of these activities must be started well in advance of the production of the finished system. In order to establish a standardized approach for the systematic gathering of the information which is relevant to the early planning of training regimens and training devices, the Naval Training Device Center has developed and refined a process called Training Situation Analysis (TSA).

TSA is a method for gathering, analyzing, and presenting the information, about a new or existing system, which is relevant to the decisions which need to be made about training support equipment. It is intended that Training Situation Analysis be conducted by an expert team of Center personnel which has the blend of talents and experience required to understand the human involvement, as well as the technical details, in a complex man-machine system. Although the initial goal of TSA was to facilitate training and training device decisions for systems which are in early stages of development, the process has been found equally effective when applied to operational systems for which a training program must be designed or modified. In fact, the method is likely to produce a more appropriate training solution for existing systems, to the extent that the available information is more comprehensive and reliable.

1. Historical Perspective

Military training device decisions of the past decade have been founded either upon a formal method of task analysis or upon informal assessment of the training situation. The informal approach has produced some effective training programs. However, it requires that persons with broad experience and psychological sophistication perform the planning function. The informal approach is unsuccessful whenever relevant information is overlooked, misinterpreted, or misapplied. The greatest defect of this approach, however, is in the difficulty of verifying or challenging the training solution which is produced. One can never know, about any training program so devised, whether all of the important aspects of the man-machine system have been considered, whether training has been prescribed for those system segments which have the greatest relationship to system effectiveness, nor whether the recommended training program is particularly well suited to teaching the specific skills and knowledges which must be conveyed. It is extremely difficult to assess, before the fact, whether each training dollar will be well spent.

The planning of a training program for a complex man-machine system is a difficult and complex process. It requires the integration of knowledge, techniques, and skills from the fields of engineering, operations analysis, and psychology. Although training has been going on for a long time, the techniques for determining the content of training and for establishing training device requirements are not very far advanced. Both rely heavily upon gross judgments based on partial information about the training problem.

Training Situation Analysis is a process whereby decisions about training and training devices will be more closely tied to the facts that bear on the particular training problem. TSA does not do away with the need for expert judgment, however. The value of the experience of experts is not lost. Instead, TSA organizes the questions

on which judgments are required into more manageable groups, and forces consideration of questions which might otherwise be overlooked. It focuses the expert's attention on specific problems, rather than allowing judgments to be made on broad poorly defined questions.

For reasons lost in the history of the development of training technology, certain traditions and beliefs about training have become accepted. One example is the belief that operational equipment is the best training equipment. The design of training and training devices has fallen into a pattern based upon such traditions and beliefs--- a pattern which is well suited to some training situations but is inappropriate for others. The systematic, step-by-step approach of TSA to training device decisions preserves those traditions and beliefs that are valid, while eliminating, for good reasons, those which do not hold up under a close scrutiny of the decision processes.

Previous attempts have been made to develop formal methods of task analysis, so that training decisions may be based upon something more substantial than intuitive judgment. However, the articles in the literature dealing with task analysis describe methodologies that are either too general or too specific to be useful. Some previous methods of task analysis have been devised to serve a large number of purposes. In addition to the planning of training programs, the authors claim their method of task analysis may be used for personnel selection and test development, writing of job instructions, operations analysis, human engineering of the equipment, etc. These methods typically call for a large volume of information to be amassed, but little consideration is given to how each item should be applied to the decisions which have to be made in planning training programs. Other articles describe task analyses which were performed on specific systems. They describe how one particular training problem was investigated and the process by which a specific training solution was adopted. However, they fail to provide a generalizable, widely applicable procedure, whereby a sound program can be built in response to nearly any training problem. It was to fill this gap that the development of Training Situation Analysis was undertaken.

2. Philosophy of TSA

Training devices for complex man-machine systems are most effectively designed as integral parts of a training program to provide the means by which the tasks to be learned can be demonstrated to the input trainees or practiced by them. Each component of the training program is introduced in response to a specific feature of the training problem. Training devices are designed to fulfill specific needs of the training program.

Effective training device design begins with a conceptualization of each task in the system and a description of the manner in which it is to be performed. Each task is described in terms of selected attributes. The pattern of these attributes which a task possesses has implications for the manner in which training should be conducted and the training devices appropriate to complement that training. An inventory is made of the skills and knowledges which a skilled task performer must possess and those already within the repertoire of the typical input trainee expected for this system. The performance capability of the entering trainee is subtracted from the skill and knowledge requirement of each task. This difference represents the training requirement for that task, for those trainees. Training principles are applied, yielding a general statement of the appropriate course content and the kinds of practice which would bridge the gap represented by the task training requirement. The cost of bridging this gap is estimated for each task which requires training. On the basis of the cost and the potential gain in performance attributable to training, each task is assigned a training priority. Training devices are then designed to provide the equipment on which course content is presented or practice is held.

Training Situation Analysis is a procedure for assuring that training devices are introduced to fill particular needs in a training program---a program which is based upon sound training principles, and is tailored to the task, the trainees, and the pocketbook.

B. General Description

Training Situation Analysis may be viewed as a process scheme for getting from a training problem to a training solution. The five stages of TSA and their interrelationships are shown schematically in Figure 1. The process is presented in terms of distinct stages performed in a specific sequence. In actual practice, however, the stages may overlap considerably, and it would often be difficult to discern where one ends and the next begins. A considerable portion of the analysis associated with the later stages is typically begun in the earlier stages.

System Familiarization--The process begins with the analysts' gaining an orientation to the training problem, the system structure and flow, and the equipment which is involved.

Task Analysis Method (TAM)--Next they gather the particular information, about human performance in the existing or contemplated system, that is relevant to the decisions which must be made about training and training devices. The resulting set of task descriptions delineates the relevant attributes of each task.

Functional Training Requirements (FTR)--Through the application of training principles, the profile of relevant attributes characteristic of each task is translated into the functional requirements of the training regimen indicated for that task. Functional training requirements state, in fundamental terms, what needs to be done to bring about the acquisition of each task, without stating in great detail how the program is to be implemented. Derived by means of a method based upon learning theory and empirical findings, the functional training requirements serve as the foundation for the remainder of the TSA process. At this point, the training program begins to take shape.

Training Analysis Procedure (TAP)--It is now possible to obtain estimates of training costs and the effect of training upon performance levels. This information is transformed by an operations analysis procedure into a ranking of tasks according to training priority.

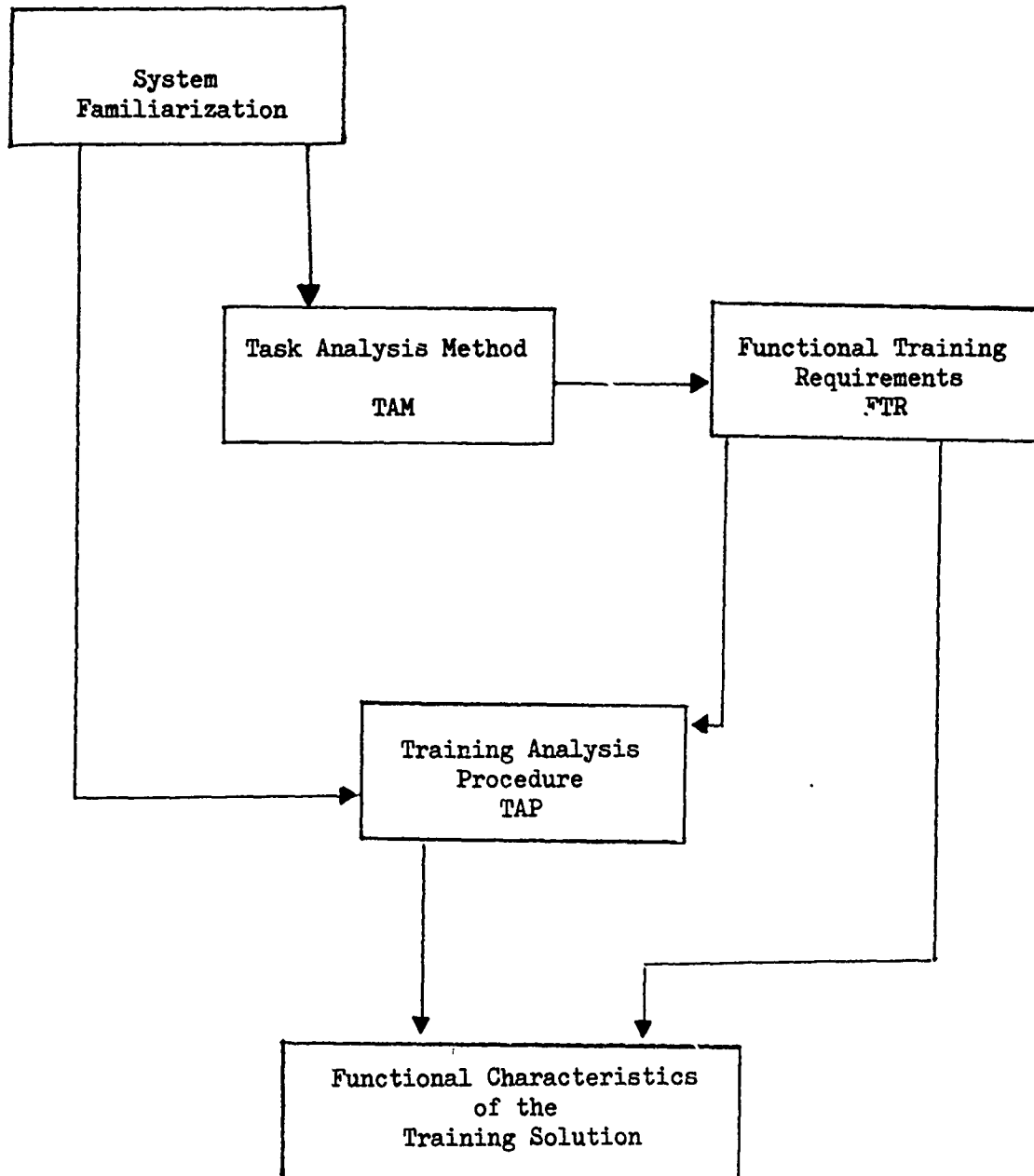


Figure 1. The Major Stages in Training Situation Analysis

4
4
Functional Characteristics of the Training Solution--The analysts set forth the functional characteristics of the training program, designed for the acquisition of the tasks selected in TAP and based on the functional training requirements determined previously. In describing the training devices, training equipment, or training system, the analysts will consider technical feasibility, utilization factors, and training context.

C. Current Status

Although a considerable amount of developmental work has preceded the publication of this document, Training Situation Analysis is presently not a polished procedure which can be immediately applied to any training problem whatsoever with assured success. A good deal of research remains to be done. Portions of TSA are still to be developed; other portions of the method, which are in a more advanced stage of development, are undergoing continual refinement and validation.

This document contains a general description of the Training Situation Analysis concept, devised by personnel at the Naval Training Device Center, as well as specific procedural instructions for applying two of the techniques that have been developed. These two techniques are called Task Analysis Method (TAM) and Training Analysis Procedure (TAP). They were devised under the direction of the Center, by Applied Science Associates, Inc., and Dunlap and Associates, Inc., respectively. TAM is primarily a method for obtaining the information necessary and sufficient for arriving at fundamental decisions about the characteristics of the training and the training devices appropriate for each system task. TAP, on the other hand, is basically a procedure for utilizing performance and cost information to derive a ranking of tasks in the order of the contribution their training can make to system performance per dollar spent in training.

NAVTRADEVGEN 1218-4

In conjunction with the theoretical development described in NAVTRADEVGEN Reports 1169-1 and 1218-1, the present report represents the current state of development of TSA. The most significant gap in TSA, at present, is an explicit procedure for translating task description data into a set of functional training requirements. However, the theoretical foundation for the development of such a procedure has been established by Folley¹.

¹Folley, J. D., Jr. Development of an Improved Method of Task Analysis, NAVTRADEVGEN 1218-1, Applied Science Associates, Inc. Appendix A.

SECTION II

SYSTEM FAMILIARIZATION

A. Classes of Data

The first task of the team of training situation analysts should be to understand the training problem to be solved and the system that the input personnel will be trained to operate. This orientation will serve as the groundwork for the remainder of the TSA process. Without a fundamental understanding of the training problem and the system, the final training solution may be wide of its mark.

1. The Problem

The training support problem to which the Team is to apply itself should be thoroughly reviewed. If the statement of the problem has obvious defects, they should be worked out with the user or training agency very early in the TSA. In reviewing the problem, the following questions should be considered:

What is the training problem?

Is the stated problem the one which needs to be solved?

How can the problem be better stated?

What constraints are imposed upon the training solution?

Are they realistic constraints?

If the problem seems well stated, these questions should be kept in mind as the TSA is being performed, until such time as some aspect of the original problem seems inappropriate. Sometimes the faults of the problem statement do not become apparent without a full investigation of the training situation.

Occasionally, the TSA team may be able to detect weaknesses in the training problem, as it is originally stated. The problem may

be incompletely or ambiguously stated. The problem statement may imply a specific solution or class of solutions which the TSA team is not prepared to accept before the analysis is performed. The limitations of funds or time, if these are included in the problem statement, may be unrealistic in view of the stated training goals. Such matters should all be cleared up before proceeding with the TSA.

2. The System

One of the primary purposes of this first stage of TSA is to familiarize the Team with the system for which training is to be planned. The basic data of TSA are gathered through interviewing and the examination of documents. Unless the Team is thoroughly familiar with the system objectives, structure and flow, the role of the human operators, and the equipment capabilities and nomenclature, there is likely to be a good deal of misinterpretation of the basic data and a significant lack of respect and patience on the part of the informants who are interviewed.

The classes of information to be obtained about the system may be organized around three headings: system objectives, system characteristics, and man-machine characteristics. Some of the more important questions to be answered under these three headings are listed below.

System Objectives--What is the primary mission of this system? What other missions is it able to perform? What specific functions has the system been designed to perform? Have any criteria or tolerances of successful system performance been established? What is the tactical concept behind this system? How does it affect existing tactics, strategy, and doctrine? How does this system fit in with other broader systems? How does it interact with systems at the same level or at subordinate levels? Is it a new system designed to meet new needs or is it an improvement on an existing system? How did the requirement for it originate? Has any operations research been done on it?

System Characteristics--What are the principal functional components of the system? Which ones have been designed especially for this system? What are the major subsystems? What are the interrelationships among subsystems? What are the events in a typical system mission? What are the inputs to the system? Are there different classes of inputs? For each class of input, what is the typical rate--what is the maximum rate that the system can handle? What operations does the system perform on the inputs? What determines the operations that will be performed on a particular class of inputs? What are the required outputs? To whom do they go--in what forms? What are normal levels of system output? How can the quality of system outputs be evaluated? What are the minimum acceptable levels of system output? What is the maximum system capability for the production of outputs?

Man-Machine Characteristics--What is the role of human operators in the system? How many persons will operate the system? What will be their differential duties? What sensory inputs will the operators receive? What are the various displays called? What controls will be operated? What happens when various controls are activated? What will the various operators do during a typical mission? How will they handle unusual contingencies which arise? Will all of the operators work independently or will some work together as a team? Have qualifications been set up in terms of the intelligence, training or experience necessary for the different positions? Have standards of speed or accuracy been set up for any of the tasks? What sorts of situational or environmental stresses will the operators be under? What special precautions must be taken for the sake of the safety of personnel or equipment? What aspects of the system will cause special difficulties in training?

B. Sources of Data

In this important phase of TSA, several different data sources may be used in formulating an accurate description of the system. These include:

NAVTRADEVCEEN 1218-4

- . System Documentation
- . System Observation
- . Personnel Interview

The following sections provide some guidelines for using these sources effectively in acquiring an understanding of the system.

. System Documentation

The initial effort in the system familiarization phase should be devoted to gathering all available documentation pertaining to the subject system. These documents may include manufacturers' or service-published system operation manuals, field manuals, operating command SOP's, or, in rare instances, previously compiled task analysis data. These documents should be reviewed thoroughly and studied in detail to provide a basic understanding of the system mission, operating modes, number and kinds of consoles and control-display devices, and number and kinds of operating personnel and their general functional responsibilities. From these sources, the analyst should attempt to establish a first-cut description of system flow. It is often helpful to chart the flow of events. The analyst may use his own method of flow-charting or adopt the OSD technique described on page 14.

The level of understanding which can be acquired from documents depends upon the number of documents and the relevance of the subject matter of the documents to the areas of concern. Typically, the areas of most vital interest to the TSA team, those having to do with human participation in the operation of the system, will be least adequately described. The Team will have to turn to other sources of information.

. System Observation

Having acquired a preliminary orientation to the system from the available documents, the next important step to be taken, wherever possible, is to observe the system as a physical reality. Preferably, the

system should be seen while it is operating, on either real or synthetic data. Of greatest benefit is to receive a "talk-through," as the operation proceeds, from knowledgeable personnel who are not actually participating in the operation. Several such observations may be required, depending upon the complexity of the system. Whenever possible, it is advisable to observe the way in which several operators perform the same task. In this way, the analyst is better able to differentiate between the attributes of performance which are characteristic of the task and those which are characteristic of a particular task performer. During the first observation, the analyst should confirm his understanding of the system as derived from the documentation. Any discrepancy between his understanding of the system operations and equipments as derived from the documentation, and his observations during system operation, should be cleared up at the earliest opportunity.

When observing a system in operation, particularly a system with several operating modes, it is important to note the conditions under which the system is operating or the mode in which it is operating. If modes shift during the observation, it should be determined what events precipitated the shift and what changes in procedure, function, or responsibility took place.

While in the observation situation, the analyst should attempt to acquire the confidence of the operating personnel and enlist their cooperation for future performance data collection. Every effort should be made to explain the purpose of the study and its potential benefit for future training in the subject system. Operating personnel can prove to be a valuable source of information during all phases of the TSA process.

. Personnel Interviews

Wherever possible, system description should be developed with the aid of operating personnel. A series of discussions with these knowledgeable individuals will generally prove to be the most valuable

portion of any visit to an operational site. The analyst should interview as many operators as he can. The greater the number of operating personnel that are interviewed in connection with each task, the more reliable will be the analysts' information. The analysts' first exposure to system personnel may be during the first observation period. At this time, the analysts should seek to make their understanding of the system conform to actual operating procedures. The system flow should be established and confirmed. It is particularly important to get firsthand knowledge of possible contingency situations (see p. 25) and how they are handled. Quite often, the manner in which the system copes with contingencies is a matter of local SOP and is not documented.

The nature of the tasks, particularly those which are unique to this system, should be discussed with operating personnel in anticipation of collecting data in the later stages of TSA. At this time, the task should be completely understood, so the future interrogation may be properly structured and efficiently conducted.

C. The Operational Sequence Diagram (OSD)

An understanding of the sequence of events in the operation of a system may be considerably enhanced by the use of graphic techniques. One of the techniques currently being employed in system analysis is the Operational Sequence Diagram, or OSD². The OSD is a tool for representing pictorially the interactions among the men and machines in a system.

The use of OSD's within TSA may be considered as an optional technique which can serve the purpose of testing, crystallizing, and extending the Team's understanding of the basic processes of which the system is composed. It is optional in the sense that if a thorough

²Brooks, F. A., Jr. Operational sequence diagrams. Inst. Radio Engrs. Trans. Human Factors in Electron., 1960, 1, 33-34

analysis of the system from the standpoint of human involvement has been previously performed there is no need to repeat the process. If there exist many excellent operator-oriented documents with standard procedures, time-line charts, information flow diagrams, and statements of duties and responsibilities, there may be little need for OSD's. System familiarization can be rapidly acquired without this technique. Unfortunately for TSA analysts, this is not the usual state of affairs. Typically, nearly all of the available documents are devoted to describing the functioning and capabilities of the equipment. They are written for the engineer, not for the training specialist.

When the analysts must gain an understanding of system functioning through intensive independent investigation, the OSD provides an excellent means for assuring the uniformity, completeness, and accuracy of that understanding. Preparation of OSD's forces the analysts to be comprehensive in their understanding of the system. It demands continuity in system flow; it establishes the relationships between operators and equipment (and, more importantly, among tasks). Once prepared, it serves as an excellent basis for discussion with operating personnel in confirming the analysts' understanding of the system.

The basic components of the OSD are various geometric figures coded to denote the elements of any operational sequence (see Figure 2). These figures are drawn in columns which represent the various positions and equipments in the system. They are interconnected by solid or dashed lines which represent the sequential interrelationships among elements. OSD's are often drawn with a vertical time scale along the left border. The length of the vertical solid interconnecting lines represents time between the elements. Horizontal lines show information links among equipments and operators. A dashed vertical line is used to indicate a time delay in an operational sequence.

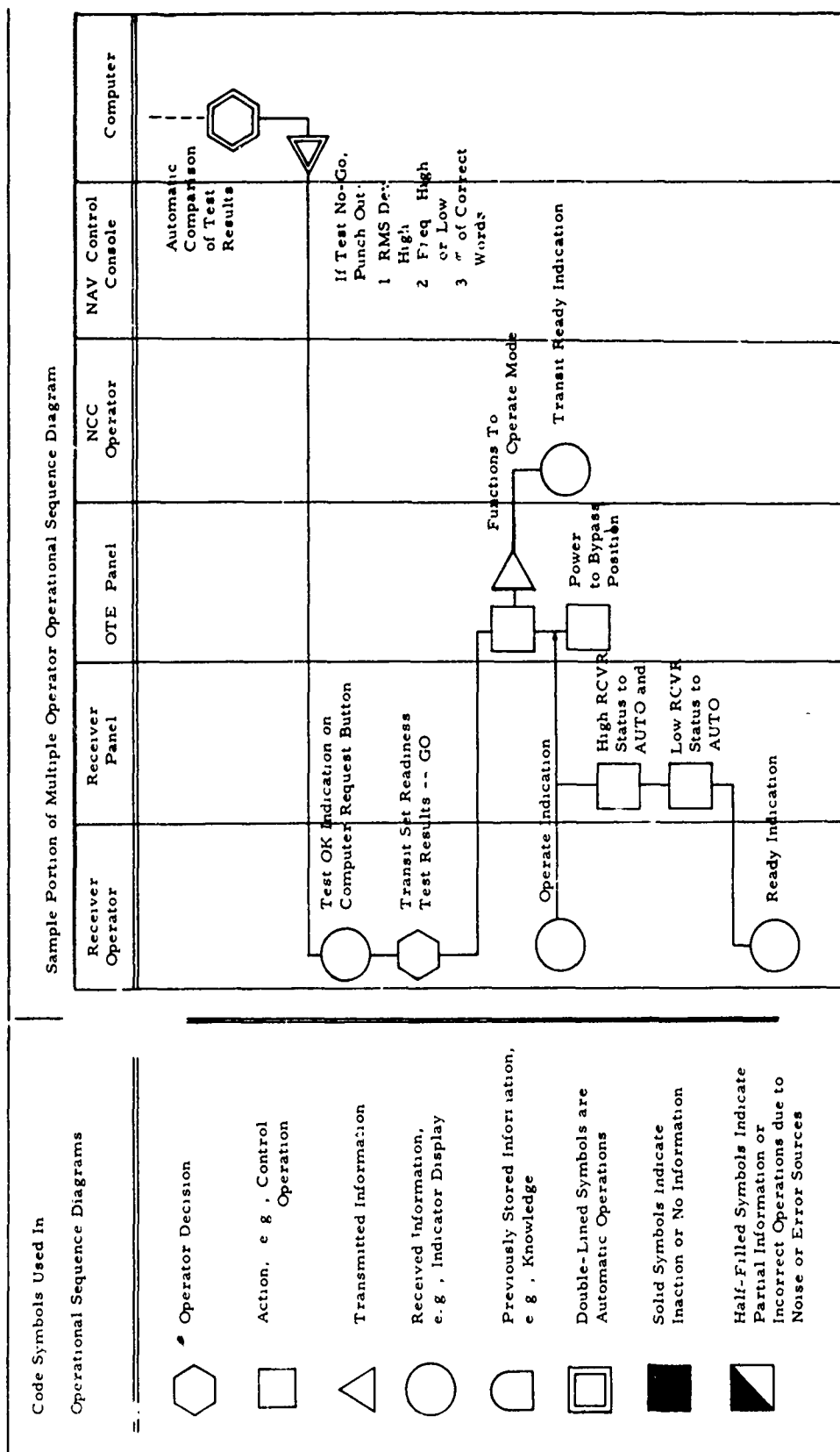


Figure 2. Illustration of Operational Sequence Diagram Symbols and Format.

Squares on the diagram are used to indicate actions. Triangles are used to indicate the transmission of information, in the broadest sense of the term, and circles stand for the reception of information. Decisions or discriminations* are shown by hexagons. A cup-shaped symbol is used to represent information storage. With this symbol, information may be shown being placed into storage or withdrawn from storage.

Whenever symbols are drawn with a single line, they represent human behavior. Double-line symbols represent operations performed automatically by machines. A symbol which is filled has the meaning opposite from that of a line-drawn symbol of the same shape. Filled symbols are most often used in conjunction with hexagons (decisions) to show that one possible alternative of the decision is "inaction."

* The analyst should be cautioned that the distinction between decision and discrimination which is obscured in the OSD must later be preserved when the analyst undertakes the TAM analysis of the system (see p.53).

SECTION III
GUIDELINES FOR
TASK ANALYSIS METHOD (TAM)

A. Introduction to TAM

The Task Analysis Method (TAM) has been devised to direct the attention of Training Situation Analysts to the aspects of a complex man-machine system which will help them decide how training for that system should be conducted. It is basically a procedure for obtaining and abstracting selected information about the human participation in a system. However, no set of suggestions or rules can reduce task analysis to a simple, routine job. The description of human behavior is too complex, and the number and variety of tasks too great to permit reduction of task analysis to a simple routine. These guidelines will not do the job for the analyst. They will, hopefully, help him do his job better.

These guidelines have been set up so that only the information necessary and sufficient to meet the objectives of task analysis is collected. The amount of information to be collected, therefore, probably is less than in other forms of task analysis. The amount of effort required of the task analyst is probably about the same as with earlier methods, however, because the guidelines require collection of some information that is difficult to obtain.

The primary difference between the present method and previous methods is the direction in which the analyst's efforts are channeled. Under previous methods, for example, the details of every step of a lengthy procedural task may have been written out; under the present method this part of the task is merely identified as "procedure following." The major effort is then directed toward determining the factors associated with following that procedure which may generate training requirements most appropriate to that specific kind of activity. The same approach is used with other types of activities within tasks.

This introduction presents some basic ideas that the analyst should understand before getting into the instructions for task analysis. The remainder of this section presents the stages of the task analysis method essentially in the order in which they would normally be performed. Examples are given to illustrate the type of data required, and discussions of special problems or techniques are included where they clarify the instructions.

1. The Nature of Task Analysis

. Task Analysis vs. Task Description

Task analysis is a process in which a task is examined and its characteristics, in terms of certain attributes, are identified. The particular attributes which are used depend on the objectives of the analysis. Task analysis produces task descriptions.

The task description is a product, a thing, a body of information, a set of statements about a task which characterize that task in terms of selected attributes. The task description resulting from task analysis is then used as the basis for certain decisions. In the case of TAM, the task description is applied to decisions about training. These guidelines suggest ways of performing the task analysis in such a way that the resulting task description is most applicable to training decisions.

. The Content of Task Descriptions

Describing a task is like describing a person. You can say many things about either. The choice of information to be mentioned depends on what you want to do with the description. For example, if you want to describe a man to his tailor, you would use a standard set of body measurements expressed in the form of clothing sizes. The size of the person is the information relevant to the tailor's purpose of making

a suit. In describing the same person to a personnel manager, you would be much more likely to say something about his aptitudes, intelligence and personality characteristics. These are the kinds of information the personnel man needs to know about the person in order to decide whether to hire him. Clothing sizes do not help.

In describing tasks, picking the right information is also important. If you were going to redesign an operator's panel, a link analysis of the sequential movements would be very useful. In deciding on training requirements, the kinds of behaviors present in the task would be more relevant.

It is important, therefore, to keep in mind that task analysis is the process of collecting particular kinds of information about the tasks. Merely collecting a large amount of information does not necessarily result in a good task analysis.

Certain kinds of information about tasks are more easily obtained than other kinds. Going back to the analogy of describing a person--it is much easier to determine his suit size than to obtain a description of his personality characteristics. In general, the reason for this difference is that there exists a standard, generally accepted method and scale for determining suit size. This is not true for personality.

Task analysis is similar in that some attributes are easily identified, while others are not. It is relatively easy to determine the number of controls and displays that must be used in a certain task. Determining the behavioral requirements of a task and describing them in a meaningful way is a tougher problem. There is no standard, generally accepted way to describe behavioral requirements meaningfully. At the present state of the art, you cannot go to a standard behavior list and pick out the ones that apply to the particular task you are analyzing.

These facts have two implications for the task analyst:

(a.) Because some kinds of task data are easier to get than others, there is a temptation to fill up or fill out the task description with this more readily available information. The substitution of quantity for relevance is not very helpful. The personnel man cannot legitimately decide whether to hire an applicant on the basis of a complete listing of all the applicant's clothing sizes. Training decisions cannot be made on the basis of task data which are not relevant to training, no matter how much of this non-relevant information is collected.

(b.) Because the most important kinds of task data are also the most difficult to obtain, great demands are placed on the judgement, insight, intelligence, and information-collecting ability of the task analyst.

2. The Nature of the Task Analyst

. Characteristics

In order to do his job well, the task analyst must be a little like the chaplain in some respects--he must be a tower of strength and of tolerance, and have some appreciation of the problems of everyone he deals with. The variety of situations in which he must work, the different kinds of people he must deal with, and the fact that he almost always intrudes himself and his questions into someone else's ongoing work emphasizes the inherent difficulty of doing task analysis.

The task analyst's strength must lie in his persistence to seek out and obtain the required task data. Every item of information called for in these guidelines fills a specific need in making training decisions. Omission of any item means that some training decision will have to be made less objectively and less effectively, with the ultimate

result that training, and, consequently, system operation, will probably be less effective. For example, if data on contingencies are inadequate, ample provisions may not be made in training devices or in the training program for trainees to practice handling the kinds of contingencies that may arise in task performance.

. Adaptability

Task analyses vary widely in their scope and information requirements. Sometimes analyses will be required on all tasks in a large weapon system. In other cases an analysis of a single task, such as firing a rifle at a moving target, may be the extent of the requirement. The analyst must adapt his methods and approach to meet these different needs.

. Overcoming Resistance

Because he intrudes his difficult questions into the normal work routine of other people, the task analyst must expect some resistance to providing the data he needs. He must tolerate and "wait out" what in some cases may seem unreasonable objections or questions regarding his work if he is to obtain the required data. For example, personnel in operating units may fail to see the important role that task analysis plays in ultimately providing trained replacements for their unit, or in providing personnel adequately trained on new equipment which the unit may be receiving in the future. In consequence, these operating personnel may be reluctant to interrupt their activities to provide the needed task data. The task analyst must be ready and able to show them that the information he needs is important.

. Obtaining Accurate Information

In most cases, the task analyst cannot observe performance of the task he is to describe. Frequently he cannot even see

the equipment involved. He has to depend, rather, on second-hand information obtained from system experts or other informants with varying degrees of information about the task. In many cases, these informants will have little knowledge or appreciation of the problems and purposes of task analysis or Training Situation Analysis. If he is to obtain accurate task descriptions, the task analyst must develop considerable skill at asking questions, and at conveying to his informants an appreciation of the kinds of information needed and the way in which it will be used. It is also important that the analyst ask the same questions of more than one informant. This will enhance the completeness and the accuracy of the resulting task descriptions.

The task analyst must realize that most of his informants will have a point of view different from his, and that the questions he asks and the answers he gets may have very different meaning to the informant than to the task analyst. For example, in trying to learn about a task, the analyst may ask "What is the most difficult part of this task?" The system designer-informant may report, for example, that accurate aiming of the missile is most difficult. From his point of view--presumably system performance--this may be true. Behaviorally, however, the operation may be as simple as pointing an automatic theodolite toward a specified point and pressing the "automatic lock-on" button. The informant has given what to him is an honest, accurate answer to the question. But the answer, if accepted at face value, may give a very erroneous impression of the nature of the task involved.

The system designer may not have been accustomed to factoring out the human operator's part of the operation and analyzing it separately. The task analyst must be capable of evaluating the answers given by his informants and be ready to probe with more questions to get the information he needs. For example, in response to the above answer, the analyst might ask what aspect of aiming the missile made the task

difficult. From the informant's answer it may be apparent that he is not talking about human participation. The analyst can then inquire further about the aspects of operator performance which made the task difficult.

3. Some Basic Definitions

Activity--The term "activity" has a special meaning in TAM. It refers to a class of task behaviors. TAM describes every task in terms of the apportionment of the operator's attention among six activities (see p 50ff): procedure following, continuous perceptual-motor activity, monitoring, communicating, decision making, and non-task-related activity. The resulting profile of activities has relevance to the training decisions which must be made about the task.

Event--A discrete, identifiable act or occurrence. Examples:
(a) Depress "Power" button, (b) Time reaches 0900.

Task--A collection of activities that are: (a) performed by one person, (b) bounded by two events, (c) directed toward achieving a single objective or output, and (d) describable by means of the method set forth in these guidelines, so that the resulting task description conveys enough information about the task to permit the necessary training decisions to be made.

Position--The group of tasks assigned to one person in an operational or maintenance situation.

Block or Major System Function--A group of tasks or system operations occurring during the same period of time, all directed toward achieving the same sub-objective in the mission of the system. Human participation may be partially or completely absent from a block. Typically, however, a block is composed of tasks performed by the operators.

Performance Requirements--The minimum level of performance (for a task, block, or system) that would be considered acceptable--that would not jeopardize accomplishment of the mission within prescribed limits of time and accuracy.

Adverse Conditions--Environmental or situational factors which act to degrade or disrupt task performance. When adverse conditions are present, the operator generally has to put forth greater effort in an attempt to maintain normal procedures and a normal rate of performance.

Contingencies--Events occurring during task performance that cause disruption of "normal" or expected activity in the task.

4. Phases of Task Analysis

Training decisions are not made all at one time, but are made in gradually refined stages. Task analysis can and should progress in the same way. After a certain amount of information is obtained, training decisions can be made to a certain level of detail. As more task information is collected, the training decisions can be refined. For example, as soon as it is determined that a task contains relatively difficult tracking behavior, the decision can be made that a device will probably be needed on which trainees can practice this part of the task. Funds and time can then be allocated for developing such a device and for including the practice in training. Later analysis of the task may indicate the critical cues and responses in the tracking part of the task. This added information permits decisions to be made about the specific characteristics of the device, such as the aspects of the task which need to be simulated and the required degree of simulation.

In keeping with this kind of progression, task analysis proceeds from large units of system operation to successively smaller units, increasing the amount of information obtained about human participation as it progresses.

In developing a task analysis, it is necessary to obtain a reliable list of tasks as a starting point. It is almost impossible to specify a single approach to task identification that is best for every system and every situation. In some cases it is best to ask about and to list tasks directly. In other cases it is helpful to divide the overall system operation into major operating stages (herein referred to as blocks), and then identify the individual tasks within each stage.

The operating stages approach is most effective in those cases where the total of system activity is of fairly long duration, and proceeds in readily identifiable blocks. An example is the receipt, preparation, and firing of a large weapon. In this example the stages or blocks might be:

1. Accept and inspect weapon
2. Assemble weapon
3. Check out weapon
4. Position weapon
5. Check assigned targets within range
6. Establish ready-to-fire condition
7. Prepare to fire and fire
8. Travel to target
9. Scheduled maintenance
10. Unscheduled maintenance

Each of these blocks will contain many tasks, or system operations, which will be identified block by block.

Assuming the more inclusive approach for this presentation, the phases of development of task analysis and the kinds of information obtained in each phase are shown in Table 1.

Since the starting point for task analysis will vary from system to system, the task analyst will have to use his judgment in each case so as not to repeat work already done under a different title. The major steps given below are the steps that have to be done. If any have been completed at the time task analysis is begun, obviously they need not be done again.

Phase	Units within which data are obtained	Kind of data obtained
Development of:		
1. System Block Analysis (SBA)	Whole System	Major system operations, arranged according to sequence and time, when possible.
2. Task-Time Charts (TTC)	Operating stages or whole system	Identification of tasks and relationships among tasks.
3. Functional Task Descriptions (FTD)	Tasks	Activities within tasks and relationships among activities.
4. Behavioral Details Descriptions (BDD)	Activities in tasks	Detailed characteristics of activities.

Table 1. Stages in Task Analysis and Kind of Data Obtained in Each Stage

B. Development of System Block Analysis

The System Block Analysis is primarily a list of major blocks of tasks or major system operations into which a system can be partitioned. It also indicates the sequence in which the blocks occur where sequence is important. If the blocks do not occur in a particular order, this too is indicated. In some systems the blocks occur in series; other systems will have blocks which are concurrent or which overlap in time.

The word "block," as it is used here, refers to a group of tasks or major system operations, all of which are directed toward the same subgoal in the functioning of the system. An example of a block is "Check the missile." Many tasks may be performed to check the missile, but all tasks in the block are directed toward accomplishing that objective. When that subgoal is achieved, the men direct their efforts toward a different subgoal, and begin working on a different block of tasks.

Some blocks in a system may include no manned operations. These major automatic operations are included in the System Block Analysis for the sake of presenting a complete picture of system functioning. When such functions exist, the analyst should be aware of it, insofar as manned operations supply inputs to them or accept inputs from them. However, since they impose no need for training, they may be otherwise disregarded in the remainder of TAM.

If the system has several modes of operation you will have to treat each mode separately in the next stage of TAM (development of Task-Time Charts). Therefore, you will need to construct a separate System Block Analysis for each mode of operation.

The first step in identifying blocks is to ask the informant to give a narrative description of the typical operation of the system. During this narrative description, you should take notes and ask questions for clarification, to correct apparent inconsistencies, and to close any obvious gaps in the narrative. Then you should review your notes with the informant in an attempt to identify the major phases or blocks into which the system operation can be partitioned. Try to find logical functional groups of tasks which have a common subgoal. In some cases the informant will have a clear notion of the way in which tasks should be grouped. In other cases you may have to propose blocks that seem meaningful and reasonable to you, and confirm your judgment with the informant.

To each block which is identified, you will attach a descriptive name. The final product of the System Block Analysis will be a list of blocks. Beside the name of each block, indicate any prerequisite block or any time constraints which might apply to the initiation of that block. Some examples are:

Follows immediately after Block 7.

Performed as needed.

Performed on request.

May be begun any time after Block 13 is finished.

Performed throughout the operation of the system.

An example of part of a System Block Analysis is given in Figure 3.

Block Number	Block Name	Remarks
1.0	Accept & inspect weapon	
2.0	Assemble weapon	Follows Block 1
3.0	Check out weapon	Follows Block 2, 9, or 10
4.0	Position weapon	Follows Block 3
5.0	Check assigned targets within range	Follows Block 4
6.0	Establish Ready-to-Fire condition	Follows Block 5
7.0	Prepare-to-fire and fire	Follows Block 6
8.0	Travel to target	Follows Block 7
9.0	Scheduled maintenance	On regular schedule
10.0	Unscheduled maintenance	As required

Figure 3. Part of a System Block Analysis

C. Development of Task-Time Charts

The following description of the analysis process will assure that System Block Analysis has been performed and is being used. This phase of the analysis is intended to achieve four objectives for each block or, if blocks are not being used, for all system tasks taken as a unit. The objectives are:

1. Identify the tasks and determine which person (position) performs each task.
2. Determine typical total time for the block.
3. Determine typical task duration and coordination requirements.
4. Determine any adverse conditions which affect, in the same manner, all tasks being performed simultaneously.

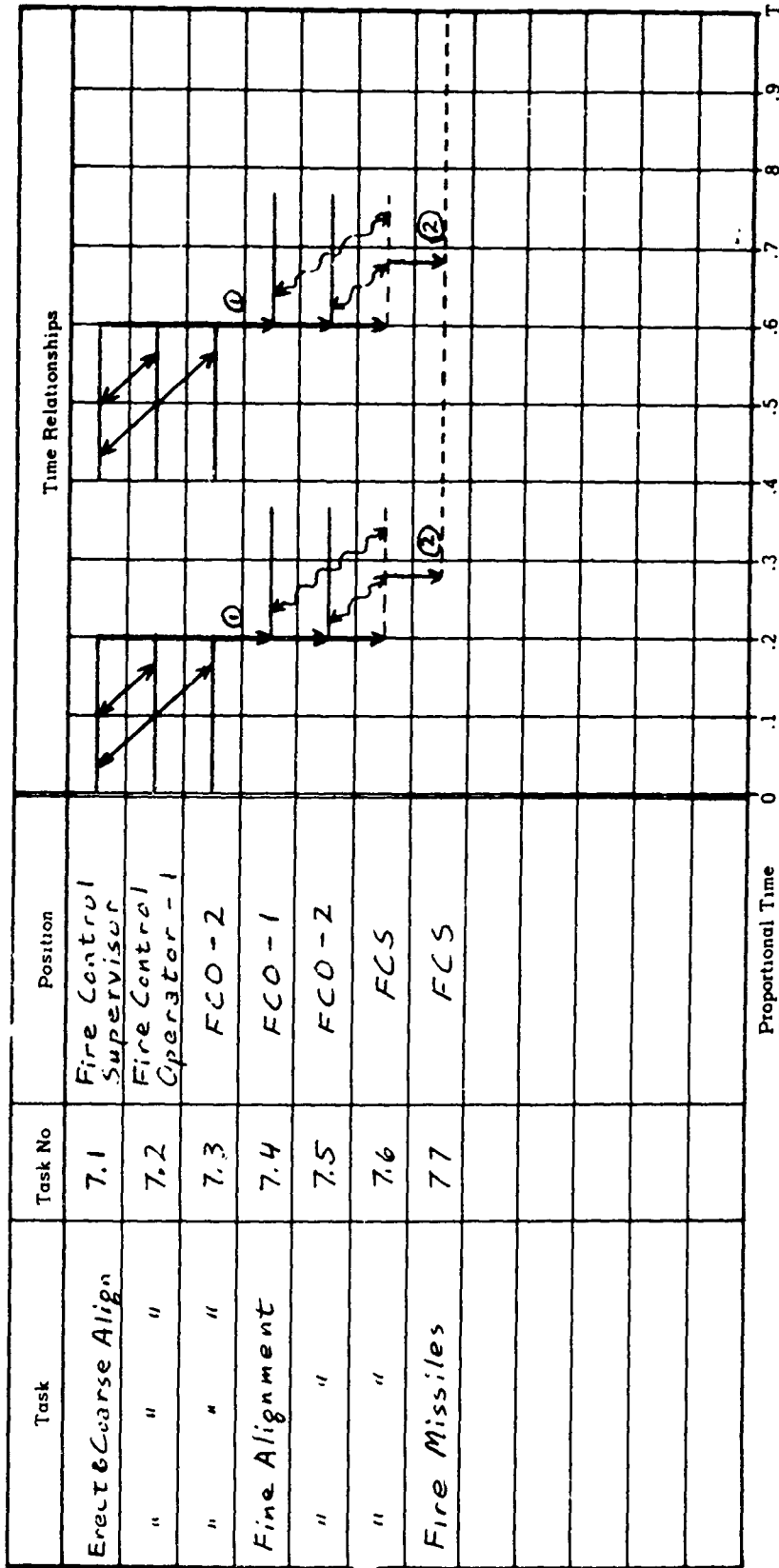
An example of a completed Task-Time Chart is shown in Figure 4. You are urged to fold out the chart and to follow this example as you read the instructions for the accomplishment of these objectives. (Note that the chart faces backward for ready reference of later pages.)

1. Task Identification

The identification of tasks is one of the central steps in TSA. It determines the course of much of the analysis to follow and influences the structure of the training program to be developed. Unfortunately, there are no hard and fast rules for identifying the set of activities which comprise a task. You will initially have to rely on interviews with system experts to provide this information. Your ability to identify the tasks in a system will improve with your experience in performing TSA. There are, however, some fundamental criteria to assist you in task identification.

A task should have an identifiable process performed by one person. This process must have an objective or output which is related to the goal or mission of the system. Not all tasks are of equal length, difficulty, or complexity, nor are they equally critical to the operation of the system. Some tasks may take seconds to perform, while others may take hours. Some may be highly equipment-oriented, procedural tasks, while others may involve only mental integration or decision making.

TASK TIME CHART

Project No. 1234Block Name Prepare to Fire and FireInformant SmithBlock Number 7.0Analyst JonesTypical Total Time for Block 25 min.Date 6 Dec 65

Show coordination, if any. Explain footnotes on the back.

Figure 4. Task-Time Chart (Front)

Tasks are bounded by two events. The initiating event may be the receipt of a signal from the external environment or the receipt of the output of another operator's task. It may be, for example, the receipt of communications, the detection of a radar target, or the lighting of a lamp on a console. The terminating event of a task is, in most cases, the achievement of the task output or the initiation of a communication indicating that the task goal has been achieved.

A task is a collection of activities that are describable by means of the methods set forth in these guidelines, so that the resulting task description conveys enough information about the task to permit the necessary training decisions to be made. This criterion for the identification of a task is a circular one, but an important one. It cannot be applied by an analyst until he is thoroughly familiar with TAM and the other stages of TSA. Nevertheless, it draws attention to the fact that data must be obtained and training decisions must be made about every unit of behavior that is called a task. As the analyst becomes familiar with the data and decisions which TSA calls for, he will acquire an appreciation of the level of behavioral description implied by the term "task" as it is used in TSA.

For example, a set-up and check-out sequence for a piece of equipment may involve ten different steps of routine meter reading and knob turning. The analyst will find that meaningful data cannot be obtained within TAM if each of the steps is treated as a task. Furthermore, the improvement in performance which is attributable to training cannot be estimated for such microscopic units of behavior. Thus, one of the necessary inputs for the TAP stage of TSA will be lacking. In any case, if the steps are indeed routine, it is the sequence of steps, and not their individual performance, which may derive benefit from training. Therefore, it is the complete set-up and check-out procedure which should be considered as a task.

To take an opposite example, it would be equally meaningless to define a task such as "operates ECM receiver" when several major

functions may be performed on this piece of equipment (e.g., detection, signal localization, and classification). In obtaining the information needed for TAM, the analyst would find that the data he was getting were too general to be of much use in planning training. He would soon see that training must be considered separately for each of the major functions which can be performed at the ECM receiver, and that each must be considered as a task.

Identification of tasks can be done in several ways. You should select the approach that best fits the situation and system in which you are working. In some cases your job will be easier and the results better if you start out with a list of positions. Each position title can then be a focal point for inquiring about tasks. In other cases identifying the tasks first, and then determining which position performs each, will be the preferable approach. If you have previously performed a System Block Analysis, you may already have a good conception of most of the tasks which are involved. As your informant was giving a narrative description of the typical operation of the system, you were probably jotting down units of behavior which might be considered tasks. This tentative list should now be confirmed with the informant and any gaps in the list should be filled with tasks.

The final set of tasks should be written on the Task-Time Chart in the approximate order of their occurrence. Listing tasks in this sequence facilitates accomplishment of some of the other objectives.

2. Determine Typical Total Block Time

Having identified the tasks in the block, you should now enquire into the amount of time which typically elapses between the beginning of the first task and the ending of the last task. This information is entered in the heading of the Task-Time Chart. If your informant has difficulty in making this estimate, you might try obtaining the information through the method of successive approximation described on page 47.

3. Determine Typical Duration and Coordination

. Proportional Duration

~~The aim of this portion of the analysis is to obtain and~~
record estimates of how the tasks you have identified fit into the block, or major operating stage, in terms of their typical sequence and their typical relative duration. It should be made clear that, at this point in TAM, there is no need to obtain firm estimates of typical task duration in units of time. That will come later in the analysis. The current goals should be to depict task duration in terms of the proportion of the total block time which is occupied by each task and to show roughly the sequential interrelationships among tasks. This is accomplished as follows:

In the "Time Relationships" (see Fig. 4) section, draw a horizontal line opposite each task name, beginning the line at the proportional time point at which the task usually starts, and ending it at the proportional time point at which the task usually ends. For example, if a task starts at the beginning of the block and ends half way through the block, start its line at time 0 and end it at .5. A task that starts 3/10 of the way through the block and ends 8/10 of the way through would have a line from .3 to .8. Figure 4 shows that the "Erect and Coarse Align" task is performed twice. The missiles in the lower firing order are typically erected and coarse aligned during the first 2/10 of the block. The missiles in the higher firing order are typically erected and coarse aligned during the middle 2/10 of the block.

Occasionally you will find an informant who will not be able to discuss task duration in terms of the proportion of block time it occupies. The informant will speak in terms of minutes, no matter how you try to steer the conversation to proportions. When this situation

is encountered, you should accept the data in terms of real time and, from a knowledge of the typical block time, compute your own proportions. At the same time, you will probably want to jot down the real time each proportional unit represents. This information will be of use in the Functional Task Description stage of TAM which follows.

. Coordination Requirements

Whether any coordination or teamwork is involved in the performance of a task can be determined by obtaining the answers to the following two questions:

1. May the task performer have to modify what, how, or when he performs his task because of the way someone else performs another task at or near the same time?
2. May someone else, performing a different task at or near the same time, have to modify what, how, or when he does it because of the way the performer of this task performs his task?

If the answer to either of the two questions above is "yes" more information must be obtained. It is necessary to determine:

1. With what other task or tasks must the task being described be coordinated?
2. What is the nature of the required coordination?

The identification of the related tasks is needed so that provisions can be made for team practice during training, if necessary. The nature of the coordination helps in deciding whether team practice is desirable.

Coordination can be described in two ways:

- . Kind of coordination
- . Closeness of coordination

Kinds of coordination--Two kinds are defined:

1. Physical, as when two men work together to lift an object; or when one holds test leads on test points and the other reads the meter. Physical coordination occurs when two task performers collaborate to achieve a single immediate objective.
2. Communicational, as when one task performer must provide information to the other in order to achieve performance of a task.

Examples: co-pilot calling out airspeeds to pilot during landing; rigger providing hand signals for a crane operator.

Closeness of coordination--Three categories are defined:

1. Start-finish. Performance of a task must await a specified cue from another task. For example, "start engine" cannot be performed until after ground power has been plugged in. In some cases the critical coordination is at the finish of a task instead of at the beginning. That is, the time at which Task X is started may not be important, as long as it is finished at the same time, or before, Task Y is finished.

Indicate start-finish coordination with an arrow from the prerequisite event to the event for which it is a prerequisite. For

example, if Task B cannot be started until Task A is finished, draw an arrow from the event at the finish of Task A to the event at the start of Task B. Figure 4 shows that "Fine Alignment" is not begun until "Erect and Coarse Align" is finished for all of the missiles in either the higher or the lower firing order.

2. Discrete feedback. Several interchanges of cues or information are required between two tasks. The information passed back and forth is discrete; although the information from one task may affect the performance of another, it will not require continuous adjustment to continuously changing cues. Example: The plotter reports a certain kind of target to CIC officer. CIC officer instructs plotter to assign a certain weapon to that target, plotter makes the assignment, plotter reports assignment made.

Indicate this kind of coordination by drawing a slant line between the middles of the horizontal lines representing two tasks requiring this coordination. Put an arrowhead on both ends of this connecting line. The slant lines in Figure 4 indicate that the Fire Control Supervisor and the two Fire Control Operators interact intermittently during performance of the "Erect and Coarse Align" task.

3. Continuous feedback. Performer of one task gets a continuous stream of cues from the performer of another task, and adjusts his performance accordingly. This need not necessarily go on for the whole length of the task. Examples: Crane operator responding to signals from rigger; carrier pilot responding to signals from landing officer.

Show continuous feedback coordination by drawing a wavy line between the middles of the horizontal lines representing the two tasks which must be coordinated in this way. Put an arrowhead on each end of the wavy line. The wavy lines in Figure 4 show that the Fire Control Supervisor and the two Fire Control Operators interact continuously during the "Fine Alignment" task.

Other rules for showing coordination:

1. If coordination is required among more than two tasks, draw as many lines as necessary to show this coordination.
2. Put a circled number on each coordination arrow for which any explanation is required and write an explanatory note on the back of the form.

4. Determine Adverse Conditions that Affect a Given Time Period

Adverse conditions are the environmental or situational factors which act to degrade or disrupt task performance. When adverse conditions are present, the operator generally has to put forth greater effort in an attempt to maintain normal procedures or a normal rate of performance.

In some cases, adverse conditions will affect all tasks being performed at the time the condition is present. Conditions that have the same effect on all tasks performed within that time period should be recorded on the back of the Task-Time Chart (Fig. 5). This does not mean that an adverse condition must affect all tasks in the block for it to be recorded on this form. It does mean that all tasks being performed

while the adverse condition is present must be affected and affected in the same manner. Adverse conditions which are specific only to some of the tasks in that time period, or which affect the tasks in that time period with different degrees of severity, should be recorded on the Functional Task Description form described later.

Three kinds of adverse conditions should be reported:

1. Environmental conditions, such as cold, heat, vibration.
2. Personal encumbrances, such as pressure suit, gloves, oxygen mask.
3. Emotional factors, such as fear-producing situations.

Often a given adverse condition will exist every time the group of tasks in question is performed. For example, escaping from a submerged helicopter will, by definition, always be done under water. In many cases, however, an adverse condition will exist only part of the time. For example, if the task were "escape from a ditched helicopter," the task would have to be done under water only part of the time. In some cases it would be possible to get out before the helicopter sank.

Other adverse conditions, such as noise or vibration, may occur at different levels of severity within the time period covered by the block. Since the student in training may be able to adapt to some of those conditions, data on the intensity of adverse conditions are required.

Often the presence or absence of various adverse conditions, or the severity of those conditions, will be different each time the tasks are performed. If this is the case, estimates should be obtained of how often the various degrees of severity are likely to be present.

After you have collected all the "adverse conditions" data, you will have filled out a four-column table like the one shown in Figure 5. The meaning of each column and suggestions for obtaining the data follow below. You are urged to fold out Figure 5 and refer to it as you read about the required entries.

Adverse Condition--What adverse condition are you describing?

The following are some adverse conditions:

Air degradation: fumes, hypoxia

Crowding

Encumbrances: boots, gloves, clothing, headset, helmet,
life jacket, mask, personal armor, suit
(pressure, G)

Fear producers: startle, isolation

G-Forces: turbulence

Humidity: too high or too low

Illumination. glare, variable

Noise: steady, intermittent, voice

Personal hazards

Rain, sleet, or snow

Temperature: too high, low, varying

Vibration

Weightlessness

Wind

Adverse Condition	Severity	Probability of Occurrence	% of Time or Prop. Limits
Noise: Intercom chatter	1	.90	100%
Temperature: cold	1	.90	0-.2
" "	1	.35	100%
" "	2	.05	0-.2

SOME COMMON ADVERSE CONDITIONS

Air degradation: fumes, hypoxia

Crowding

Encumbrances: boots, gloves, clothing,

headset, helmet, life jacket, mask,

personal armor, suit (Pressure; G)

Fear producers, startle, isolation

G-Forces: turbulence

Humidity: too high or too low

Illumination: glare, variable

Noise: steady, intermittent, voice

Personal hazards

Temperature: too high, low, varying

Vibration

Weightlessness

Notes:

- ① Erection and coarse alignment must be completed before fine alignment can be begun.
- ② Firing of first missiles in either the higher or the lower firing order must follow completion of fine alignment for those missiles.

Figure 5. Task-Time Chart (Back)

Severity--How severe is the condition? To what extent will it disrupt or degrade performance? This is very hard to determine and you will have to rely heavily on the judgment of your informant. You can describe severity at three levels, as follows:

Level 1: Will disrupt performance of an inexperienced task performer. More experienced task performers will probably have learned to adapt to the condition, so their performance will be affected very little, if any.

Level 2: The condition is severe enough to cause degradation of performance of any task performer, regardless of his experience.

Level 3: The condition is severe enough to make it almost impossible to complete the tasks within the specified performance requirements.

Indicate the level of severity by writing its number in the appropriate column. You may have to list more than one level of severity for some conditions. It is possible that a condition may occur at one level sometimes, and at a different level at other times. You indicate the relative frequency of each level of severity in the next column of the table. Figure 5 (fourth line) indicates that a severity of cold which would degrade the performance of experienced workers during the first 2/10 of the task has a probability of occurrence of .05. It is much more probable (.9) that the cold will affect the performance of inexperienced operators during this portion of the block. (See second line.)

Probability of Occurrence--Opposite each severity level you have listed for a given condition, write a number that indicates the percent of time that the adverse condition will have this severe an effect on performance. You can think of it this way: If the tasks are

performed one hundred times, in how many times out of that hundred would the first severity level occur? In how many would each of the other levels that you have listed occur? For example, noise may occur at level 1, 50 out of 100 performances; and at level 3, 5 out of 100. This would mean that this adverse condition would be recorded on two separate lines of the table.

Percentage of Time or Proportional Limits--If a significant adverse condition does occur, it may not last for the whole time period covered by the Task Time Chart. In this last column you can record the portion of the total time which would be affected, as follows:

An adverse condition at a given level of severity which is present for only a part of the time period may occur:

- a. Always during the same part of the time period (predictable).
- b. Scattered across the time period in an unpredictable manner.

If the part of the time period it will affect is predictable, that is, if the adverse condition always affects the same part, you can identify that part in this column. For example, you can indicate that this particular adverse condition, whenever it occurs, will affect the time period between .3 and .7 on the time base diagram. Figure 5 (second line) shows that the probability that the performance of an inexperienced operator will be degraded by the cold during the first 2/10 of the block is .9. However, the probability that the cold will be that severe throughout the entire block is only .35. (See third line.)

In the case where the adverse condition may occur at various unpredictable times, it will be useful to know approximately what proportion of the time period will usually be affected. In this case you

can indicate, for example, that when this adverse condition occurs, it can be expected to cover 40% of the period, even though you do not know which 40% will be affected. Simply write "40%" in this column instead of the proportional limits.

D. Preparing Functional Task Descriptions

The Task-Time Chart just completed pertains to the relationships between tasks. The Functional Task Description is aimed at describing the activities within tasks and the relationships among these activities. The following five objectives are accomplished in the Functional Task Description phase of TAM:

1. Determine the Time Performance Requirement and Typical Time for the task.
2. Identify the kinds of activities in the task and show the time relationships among them.
3. Determine what proportion of attention each activity requires of the task performer.
4. Identify contingencies, i.e., occurrences that may disturb normal performance.
5. Identify adverse conditions that apply only to the individual task.

This description is recorded on the Functional Task Description form, which is illustrated in Figure 6. You are urged to fold out Figure 6 and refer to it as you read about how these five objectives are to be accomplished.

NAVTRADEVCE 1218-4

FUNCTIONAL TASK DESCRIPTION

Descriptive
Task Title Fire Missiles (7.7)
(Action verb and object)

Project 1000

Time Performance Requirement: 20 minutes

Typical Task Time 16 minutes

Position Fire Control Supervisor

Informant Smith

Using Supervisor's Control Panels

Analyst Jones

Intercom
(Equipment, tools or other materials)

Date 6 Dec 65

Activity	Percentage of Attention	Time Relationships*									
Procedure Following	30				①			②		③	
Continuous Perceptual Motor Activity	0										
Monitoring	10				①			②		③	
Communicating	10				①						
Decision Making or Problem Solving	50										
Other (explain in notes)	0										
Non-Task-Related Activity	0										
Proportional Time		0	.1	.2	.3	.4	.5	.6	.7	.8	.9 T

Contingency	Cue	Response	Frequency	Reference**
Hatch Stuck	Red away	See Unsched. Maint.	.05	10.3
Computer No-Go	Red COMPUTER	Erased ReFire	.10	—
Computer No-Go Repeat	Red COMPUTER	By-Pass	.03	10.4

** If response is complex, cross-reference here to task created by contingency.

Adverse Condition	Severity	Prob. of Occurrence	% of Time or Prop. Limits
Crowding in on standing space	2	.25	85%

*Show initial and terminal Activity events on the Time Relationships chart. Explain on the back

Figure 6. Functional Task Description Form

1. Determine Time Performance Requirement and Typical Task Time

- . Time Performance Requirement

The Time Performance Requirement for a task is the maximum length of time the task performer could take without his performance being considered unacceptable. It is the worst level of performance the operator could display without jeopardizing accomplishment of the system mission within its prescribed limits.

Most tasks must be completed within a specified period of time if the system of which they are a part is to be effective. For example, if operational requirements demand that a missile be fired within 15 minutes of the initial system event, then no task in the countdown can take longer than 15 minutes. If two tasks must be performed sequentially before the missile is fired, the sum of their performance times must not exceed 15 minutes. The number and complexity of the tasks that must precede or follow a given task within a time-limited segment of system operation determines the Time Performance Requirement (TPR) for that task.

Determining the Time Performance Requirement for a task is usually difficult. You will rarely get an immediate satisfactory answer to a direct question about how much time is available for performance of a task. The amount of time available for performance of a task depends on when preceding tasks were completed, and how much time is taken in performance of other tasks going on at the same time.

Two constraints on performance time, however, can be helpful in determining the TPR:

- a. The sum of performance times of tasks that must be performed in sequence, rather than simultaneously, cannot exceed the total time period in which the tasks must be performed. In the missile example, if five tasks must be done in sequence to launch the missile, the total of times for the five tasks cannot exceed fifteen minutes.
- b. Unless an operator has concurrent tasks, the total of performance times for tasks performed by one person, regardless of the order in which they are performed, cannot exceed the total time in which the tasks must be performed. In the missile example, if an operator must perform five tasks, the total of times of the five tasks cannot exceed fifteen minutes.

Application of these two constraints will usually assist you in arriving at Time Performance Requirements for individual tasks.

If your informant is reluctant to state a TPR, you may be able to coax one out of him by using the following technique of successive approximation:

- a. Select a time that you guess might be a reasonable task performance time.
- b. Ask your informant "Is the Time Performance Requirement more or less than ____ minutes?"
- c. If he says "more," select a time substantially longer than the first one you mentioned, and ask him if the task can take longer than this second time that you selected, without disrupting the operation of the system.

If he says "less" to your original question, select a time substantially shorter than the first one, and ask him if the task must take a shorter time than the second time you mention.

- d. Repeat this cycle as often as necessary to get the time estimate you need.

An example of how you might "zero in" on an estimate is as follows:

<u>Your question</u>	<u>Informant's answer</u>
Can it take longer than 30 minutes?	No, it has to be done faster than that.
Must it take less than 10 minutes?	No, more than that is all right.
Can it take longer than 20 minutes?	I think so.
How about 25 minutes?	That sounds about right.

Whenever possible, the TPR for a task should be derived from a knowledge of the time constraints imposed upon larger segments of the system, as described above. Occasionally, however, this will not be possible. Some tasks are not affected by larger time constraints. In the latter case, you should base the TPR upon the informant's judgment of a minimally acceptable time standard, in terms of what a supervisor might consider acceptable. A question such as "What is the slowest the operator could perform this task without getting chewed out?" might serve. Whenever some figure other than a system-imposed TPR is recorded, this fact should be noted beside the entry on the form.

. Typical Task Time

Typical Task Time can be estimated by studying the behavioral content of the task and comparing the task in question with similar tasks within your experience or the experience of your informant. The behavioral content of the task will be identified in completing the other items of the Functional Task Description.

Typical Task Time can also be determined by asking your informant what he thinks it is. Your informant may occasionally have a tendency to give the same estimate for the Time Performance Requirement and the Typical Task Time. For the vast majority of tasks, however, these two estimates should not be the same. Be sure to ask for the Time Performance Requirement before asking for the Typical Task Time. If the two estimates turn out to be the same, make sure that your informant has grasped the difference between the two concepts and ask again whether the two times should really be the same.

If your informant has difficulty in estimating Typical Task Time, the technique of successive approximation suggested for obtaining Time Performance Requirements might again prove useful.

A few tasks with significant amounts of monitoring behavior will create problems for the estimation of both Typical Task Time and Time Performance Requirement. When tasks consist primarily of monitoring, the time devoted to monitoring is often highly variable. It is greatly dependent upon the frequency of the event-to-be-detected. For such tasks, the Typical Task Time and the Time Performance Requirement will have to be based upon the time from the occurrence of the event-to-be-detected to the completion of the task. The time devoted to monitoring will have to be completely excluded. When this is done, it should be noted on the form.

2. Identify Activities in the Task and Show Their Time Relationships

Tasks can be described in terms of six types of activities. Each type has associated with it certain functional training requirements. If it is known that a task contains one of these types of activity, the kind of training required to bring about learning of that part of the task can be specified.

Some tasks may contain only one activity. Others may contain several. In some tasks, the activities may always be performed in the same order. In others the order may be widely variable.

The following six classes of activity are defined in TAM:

1. Procedure Following
2. Continuous Perceptual-Motor Activity
3. Monitoring
4. Communicating
5. Decision Making and Problem Solving
6. Non-Task-Related Activity

Occasionally you may find a task that contains an activity which does not clearly fall into one of the basic six types defined below. This can be indicated by assigning some percentage of attention to the category labelled "other" and describing that activity under Notes. However, the purposes of this task analysis procedure will be best served if you use the "other" category sparingly.

Procedure Following--Performing a sequence of discrete steps, each of which has an identifiable beginning point and ending point. Six kinds of steps are listed below; there are others.

- a. Setting a control to a single specified position.
- b. Reading a display.
- c. Observing a display reaction and operating a control to set the display to a certain point.
- d. Fastening or unfastening a connector or fastener.
- e. Putting an object into position or removing it from position.
- f. Obtaining an item of information from a reference document.

Examples of Procedure Following:

- a. Performing a daily operating check on a radar set.
- b. Performing an aircraft pre-flight check.
- c. Replacing a defective electronic component.
- d. Typing.

Routine manipulative behavior is generally classed as Procedure Following because the operator is usually following a set procedure. Most often the procedure has been committed to memory, but sometimes it is present in the form of a performance aid. The procedure may be either fixed or branched. A branched procedure is one in which the step to be taken at one or more points is governed by the result of a perception or discrimination.

Even though a finger may have to be "aimed" at a button or a screw driver "aimed" at a screw, such behaviors should be classed under Procedure Following rather than under Continuous Perceptual-Motor Activity, in that there need be no continuous compensation for movement of the "target." Similarly, "hooking" a target on a radar display with a stylus should be classed as Procedure Following activity. The operator usually does not have to compensate for target movement while hooking it. The target does not move for one full sweep of the radar antenna.

Continuous Perceptual-Motor Activity--Observing displays and operating controls continuously in order to maintain a specified relationship between an object under the operator's control and other objects, not under the operator's control. This activity is commonly called tracking.

Examples of Continuous Perceptual-Motor Activity:

- a. Guiding a vehicle in which the operator is riding.
- b. Operating remote manipulators, including such diverse things as remote hands and hoisting cranes or draglines.
- c. Keeping a cursor on a target; either pursuit or compensatory tracking.

When performing CPMA the operator is getting a continuous stream of cues as to the position of the target (or object which he does not control) and continuous feedback as to the position of the object that he can control.

Monitoring--Observing a display, or a portion of the environment, either continuously or by scanning, in order to detect a specified kind of change.

Examples of Monitoring:

- a. Keeping watch for targets on a radar scope.
- b. Watching engine gauges aboard ship in order to be able to forestall unsafe conditions.
- c. Scanning the horizon for ships.
- d. Watching for indications of malfunction during a missile countdown.
- e. Listening for unusual sounds in an engine.

Notice that the simple act of attending to a display does not constitute Monitoring, even though displays are often monitored. Reading a display is most often a step in Procedure Following. The concept of Monitoring within TAM involves prolonged or periodic watchfulness to detect a specific class of cues or an environmental change. The moment of occurrence of this change is often not predictable.

Communicating--Receiving information and/or sending information either in words or in other kinds of symbols.

Examples of Communicating:

- a. GCA operator "talking down" pilots.
- b. Radio operator receiving or sending messages.
- c. A commander giving orders to subordinates.

Decision Making or Problem Solving--Decision Making consists of choosing a course of action on the basis of facts, opinions, and other information relevant to the decision. Problem Solving is a broad category of purposeful or goal-directed thinking which includes Decision Making.

Examples of Decision Making or Problem Solving:

- a. Troubleshooting.
- b. Analyzing targets on a plot and assigning weapons.
- c. Figuring out how to repair something with available materials.

Decision Making generally involves careful evaluation of several alternative courses of action, on the basis of how well each alternative serves the purposes of the decision maker. However, there is a class of decision-making activity in which only one course of action is considered. When an operator makes a "snap" decision on the basis of a rule-of-thumb, special knowledge or experience, or memory of what action has proven successful in the past, he is still making a decision, so long as he could have chosen to do something else or to do nothing about the situation. This class of decision should not be confused with following a branched procedure. You must distinguish between the situation in which the operator must follow an existing rule (as in branched Procedure Following) and the situation in which the operator is

free to choose any of several alternatives but acts as if his choice were determined by a rule. To illustrate the latter case: as soon as an unknown aircraft appears, a weapons controller orders an intercept without checking the availability of interceptors or the status of his ground-to-air missiles.

Non-Task-Related Activity--Activities which occupy the operator's attention but do not contribute directly to the accomplishment of the task. Many tasks do not require the full attention of the operator throughout the performance of the task. In such cases the attention-paying capability that is "left over" from the amount of attention required by the task may be said to be given to Non-Task-Related Activity.

Non-Task-Related Activity may be of two types:

1. Activity which is not related to the task being analyzed but which is related to some previous, concurrent, or future system task.
2. Activity which is related to no task in the system.

Examples of Non-Task-Related Activity:

- a. Chatting with fellow workers.
- b. Thinking about some other task to be performed.
- c. Thinking about personal matters.

• Steps in Depicting Task Activities

You will have to adjust the specifics of your approach to the particular task and situation in which you are working. The following steps, however, should guide your efforts.

Step 1--Determine the type or types of activities which the task performer should undertake at the start of the task. Opposite the first activity draw a horizontal line from the left-hand margin of the diagram to the point where the activity ends. An activity may occupy several periods within the task. The length of this line should show what portion of task time is normally or typically spent on this kind of activity.

For example, if the task performer pays attention to Decision Making or Problem Solving throughout the entire task, the line should extend from 0 to the end, as shown in Figure 6.

If a given activity occurs repeatedly within a certain time segment, and if the precise time at which it occurs is variable, draw a dashed line beside the name of the activity. Figure 6 shows that the task performer must devote intermittent attention to Communicating during the last 6/10 of the task.

Step 2--Determine the reason that the first kind of activity is stopped and another type started in the task. Indicate the stopping of one activity and the starting of another with a circled number, as shown in Figure 6. An activity may stop without another starting immediately, leaving a gap in activity (see Procedure Following and Monitoring, Figure 6). This may mean that attention to the other activities is intensified during that time or that more attention is devoted to Non-Task-Related Activity.

Explain the circled number on the back of the form, under "notes."

Step 3--Draw a line opposite the second activity to show the portion of the task during which this activity typically occurs.

Step 4--Determine the reason that the second activity is stopped and another started or intensified. Indicate with a circled number and explain as before.

Step 5--Repeat any of these steps as necessary to show all of the activities in the task.

If your informant cannot express the amount of time typically devoted to an activity in terms of the proportion of task time it occupies, accept his real-time estimates and compute proportions from your knowledge of typical task time. Note the real time units below the proportional Time Relationships scale.

3. Determine the Percentage of Attention Devoted to Each Activity

Whenever a task is performed, some of the activities which have been defined may require a large percentage of attention. Others may require very little. If an action must be performed quickly and accurately, or if the adverse consequences of not paying close attention to some activity are great, the task performer may have to concentrate very intently upon that single activity. At other times he may have to divide his attention among several activities at one time. For example, an operator may have to monitor a radar screen and communicate with his superior at the same time.

Notice that we are talking here about percentage of attention, not time. The relative amount of time an activity requires has already been presented. The amount of time spent in an activity is not necessarily related to the amount of attention it demands. It is possible to do two different activities at the same time but it is not possible to devote full attention to both at the same time.

When you introduce the topic of percentage of attention to an informant for the first time, you should attempt to convey some of the above ideas to him. If he has difficulty with the concept of "attention," you may want to say, "Attention has to do with how much an operator has to think about what he is doing while he is doing it, versus how well he can do it automatically, without thinking about it." In asking for estimates of percentage of attention you may want to use different terms. You could ask, "How do the activities compare as to the amount of concentration or mental effort they take?"

Before you try to obtain an estimate of percentage of attention from your informant, be sure you list for him again all of the activities in the task. If you simply ask, "What percentage of attention does the operator typically give to Communicating," you may get the answer, "When he is communicating he is giving all of his attention to it." This is not the information you want. You are interested in apportioning attention among activities for an entire task performance; not for just a piece of it.

One way of making these estimates is to judge, first, how much of the operator's attention will be occupied by the task and how much will be devoted to non-task-related activities. Then the total percentage of attention devoted to the task can be divided among the remaining six classes of activity. Record the percentages for both task-relevant and non-task-related activities in the "Percentage of Attention" column on the form.

It was mentioned that Non-Task-Related Activity may pertain to activity related to other system tasks assigned to the operator or it may not relate to any tasks in the system. Inquiry into NTRA of the

second type should be handled tactfully. If your informant is an operational supervisor, he may be sensitive to the slightest suggestion that his operators ever pay attention to matters which are not related to the task they are performing.

4. Identify Contingencies

Contingencies are events that cause disruption of any of the "normal" sequences of task performance.

We know, in advance, that contingencies will occur in almost every task. We also know that, in most cases, the training program will have to include some training on how to handle contingencies. The task analyst's job is to identify a reasonable sample of contingencies for inclusion in training; not to determine whether contingencies will occur. The data on contingencies are entered in the space provided on the Functional Task Description form.

Kinds of Contingencies

Contingencies are of four general kinds:

1. Equipment malfunction.
2. Human error.
3. Unusual situation occurring external to the system that affects task performance.
4. No identifiable cause, but something didn't work the way it was supposed to, or something unusual happened.

Equipment malfunction is perhaps the commonest type of contingency. Faulty operation of an item of equipment, or the occurrence of an out-of-tolerance indication usually requires modification in performance of the task.

Human error includes errors made either by the performer of the task being analyzed or by someone else upon whom normal performance of that task depends in some way.

Unusual situations are defined as contingencies that are caused outside the system, but which affect performance of tasks within the system. For example, the appearance of more targets than a certain tracking system can handle is such a contingency.

No identifiable cause contingencies are chance variations in system performance which disrupt performance but whose cause is not immediately apparent. For example, one such contingency associated with the task of escaping from a ditched helicopter is that the helicopter, as it sinks, may tip so that the door is on the bottom, making it impossible to open the door. The trapped men may not know whether the latch is jammed, the frame is warped, or the air and water pressure on the hatch are unbalanced.

• Identifying a Sample of Contingencies

The task description should contain only those contingencies that make a significant difference in the way the task should be performed. Record those contingencies which, if improperly handled during performance of the task:

- a. Can prevent the system from attaining its mission within the required time or accuracy, or
- b. Can result in personal injury or significant equipment damage, or
- c. Occur more than 20% of the times the task is performed.

Notice that a contingency with any one of these attributes is significant and should be reported.

Contingencies which have no significant effect on task performance, or which the student can be expected to handle adequately on the basis of his general experience, should be omitted. For example, one contingency might be that a control knob becomes loose and falls off the front of a piece of electronic equipment. Presumably the control can still be operated by grasping the shaft the knob was on, and you would expect that most task performers would be able to cope with that contingency without any special training. Consequently, a contingency of this kind should not be included in the task description.

The good judgment of the task analyst and his informant are about the only means for deciding whether a contingency is significant enough to include in the task analysis. If you judge that special provisions will have to be made in training so the students can learn to handle a contingency adequately, then that contingency should be included in the sample. Keep in mind that contingencies selected strictly on the basis of frequency would exclude critical contingencies that seldom occur. On the other hand, contingencies selected only on criticality would exclude the easily-managed but frequent contingencies whose very frequency of occurrence may cause a disruption of normal task performance.

Judgment is especially required in distinguishing between the contingency which is significant because it is frequent (c, above) and the event which is frequent but is handled by normal procedures and, therefore, is not a contingency. In cases where this line between contingency and non-contingency is difficult to determine, you will have to fall back on the other two criteria (a and b). If the frequent event, when mishandled, can cause a dangerous condition or can prevent the system from operating within acceptable tolerances (either from a single occurrence of the event or from the sheer weight of its frequency), that event should be listed as a contingency.

. Kinds of Information Wanted

Three kinds of information about contingencies are useful in making training decisions:

1. How is the occurrence of the contingency made known to the task performer?
2. How should he respond to it?
3. How often is it likely to occur?

How is the occurrence of the contingency made known to the task performer?--Contingencies are usually made known to the task performer when he perceives that something is happening that deviates from "the book." That is, something happens that is different from what he can reasonably expect it to be. Some examples are: landing gear does not move when pilot puts the gear level in "down" position from "up" position; someone notices a torpedo in the "armed" condition in its storage rack; a crypto message is received that is not decodable with the code thought to be in use.

Note that these contingencies could have been of three different kinds. The first could reasonably have been an equipment malfunction, the second a human error, and the third an unusual situation from outside the system. The important information for training decisions is how was its presence made known to the task performer--not what was the basic cause of the contingency.

Considering the first example, let us assume that the task is "landing the aircraft." From the standpoint of training the pilot to handle this contingency, the precise cause of the landing gear's failure to move is not important. The way the malfunction contingency came to the attention of the pilot is important. Similarly with all the other examples.

It is true that the way the task performer finally handles the contingency may depend upon the cause. In the case of the landing gear failure, he might do one thing if the cause were a popped circuit breaker and something else if he had lost hydraulic pressure. But the contingency, as the task performer first sees it, is the failure of the landing gear to move. Anything he does after that moment, such as checking the circuit breakers or the pressure guage, is done in response to the contingency. It is the responses to this first cue that must be learned in training. This is why the first item of information needed about contingencies is: how the task performer becomes aware of them.

How should he respond to it?--The task performer can make three different kinds of responses to contingencies. These are:

1. Switch to an alternate sequence of activities.
2. Continue to perform the task as well as circumstances will permit.
3. Inform a superior and suspend further attempts to perform the task in question.

The response, or combination of responses, appropriate for each contingency is information needed for setting up requirements for measurement, feedback, and scoring in training. You should record the response which is typically appropriate for each contingency. Do not merely classify each response as one of the above kinds.

How often is it likely to occur?--The information wanted here is the number of times each contingency can be expected to occur in 100 performances of the task. If necessary, you can again use the successive approximation technique suggested for obtaining estimates of task performance times, in order to get frequency estimates from your informants.

Obtaining Data on Contingencies

The major problem the task analyst has in obtaining data on contingencies is that the system experts who will provide the data often do not think in terms of what can go wrong with system performance. The task analyst has to prod them into thinking these unpleasant thoughts, and has to probe for the needed information.

If, in interviewing, you focus the attention of the informant on one topic at a time, you are likely to get more accurate and more complete information than if you ask broad questions. This focusing technique is useful in getting information about contingencies.

Keep in mind that you have twelve categories in which you can ask about contingencies, as shown in Figure 7. You can focus your informant's attention on each of these twelve categories, one at a time, in order to get reasonably good data on contingencies.

	Frequent	Prevent Mission Accomplishment	Cause Injury or Damage
Equipment Malfunction			
Human Error			
Unusual Situation			
No Known Cause			

Figure 7. Categories for Focusing Questions about Contingencies.

5. Identify Adverse Conditions That Apply Only to One Task

This is done the same way that adverse conditions were identified for blocks of tasks on the Task-Time Chart. The only difference is that the proportions and probabilities apply to the individual task instead of to a block of tasks.

NAVTRADEVGEN 1218-4

You may occasionally run across an occurrence which does not fall cleanly into either the "contingency" or the "adverse condition" category. The distinction between the two categories is as follows:

- Contingencies are task-related occurrences which require that "normal" procedures be modified.
- Adverse conditions are environmental-situational states through which the operator attempts to maintain normal procedures and a normal rate of performance by putting out greater effort.

They are both factors which increase task difficulty. If you find an aspect of the task which has properties of both adverse conditions and contingencies, you should record it under both headings on the form.

E. Preparing Behavioral Details Descriptions

This stage of the analysis results in information at the finest level of detail required in the task description. As in the previous parts of the analysis, obtaining appropriate information in this stage depends heavily upon the judgment of the analyst. The information obtained in this stage of the analysis will be used for estimating the capability of input trainees to perform the tasks, for estimating the difficulty of the training problem associated with each task, and for estimating the level of performance that can be expected after training.

Obviously, information should be collected only for those activities present in the task. While the report form (see foldout Figure 8) is organized to keep your writing to a minimum, it may be necessary for you to write some descriptive statements in order to convey an accurate picture of the nature of the behaviors involved in these tasks. Use footnotes freely. Wherever a sentence will give a more accurate picture than check marks or numbers, use it.

NAVTRADEVCE 1218-4

BEHAVIORAL DETAILS DESCRIPTION

BLOCK NO. 7.0 TASK NO. 7.7

Procedure Following

☒ Fixed - Number of steps in procedure 20 Number of SB steps 2
☐ Branched - Maximum number of steps in procedure _____ Number of possible steps which are SB _____

Describe below the kinds of SB steps involved:

If Computer lights red after Erase and ReFire, estimates needle fluctuation.

Continuous Perceptual-Motor Activity

None

Type	Displays	Controls	Control-Display Relationship
<input type="checkbox"/> Guiding a vehicle	<input type="checkbox"/> Direct or window view	<input type="checkbox"/> Steering wheel	<input type="checkbox"/> Position control
<input type="checkbox"/> Operating remote manipulators	<input type="checkbox"/> Scope or instruments	<input type="checkbox"/> Tracking handle	<input type="checkbox"/> Velocity control
<input type="checkbox"/> Keeping cursor on target	<input type="checkbox"/> Optical system	<input type="checkbox"/> Handwheels	<input type="checkbox"/> Acceleration control
<input type="checkbox"/> Other _____	<input type="checkbox"/> Other _____	<input type="checkbox"/> Other _____	<input type="checkbox"/> Lag
			<input type="checkbox"/> Backlash
			<input type="checkbox"/> Other _____

Error tolerance or accuracy required: _____

Monitoring

Object or signal to be monitored: Display Panel Lights

Display	Relevant Attribute	Other Data
<input type="checkbox"/> Scope	<input type="checkbox"/> Movement of object or signal	Estimated frequency of events: _____
<input type="checkbox"/> Window view	<input type="checkbox"/> Appearance of object or signal	Search area: _____
<input checked="" type="checkbox"/> Instruments	<input type="checkbox"/> Change in object or signal	Are events easy to detect? <u>YES</u>
<input type="checkbox"/> Optical system	<input type="checkbox"/> Other _____	If "no", how should detection be made? _____
<input type="checkbox"/> Sounds		
<input type="checkbox"/> Other _____		

Communicating

Media	Special Knowledge Requirements
<input checked="" type="checkbox"/> Radio or telephone	<input type="checkbox"/> Code <input type="checkbox"/> Format <u>None</u>
<input type="checkbox"/> Direct verbal	<input type="checkbox"/> Keyboard operation
<input type="checkbox"/> Direct observation	<input type="checkbox"/> Operation of special equipment (Specify)
<input type="checkbox"/> Written or printed English	

Decision Making and Problem Solving

☐ The operator considers only one of several available courses of action. He bases his action on a rule-of-thumb, special knowledge or experience, or memory of what action has proven successful in the past.
☐ Reasonable alternatives are generated, considered, and rejected, until an acceptable one is found.
☒ Most possible alternatives are known by the decision maker or problem solver, and all reasonable ones are evaluated.

Describe what the decisions or problems consist of and the kinds of information used in reaching the decision or solution:

Basic signal flow through parallel Select and Target channels.

Figure 8. Behavioral Details Description Form

NAVTRADEVCE 1218-4

Keep in mind that the purpose of this part of the analysis is to fill in the details to supplement all the information you have already recorded in the previous stages. Do not repeat information just to "fill in the form."

The information is to be recorded on the Behavioral Details Description form. If you need additional space for your notes, attach separate sheets.

Many of the items on this form are self-explanatory or have been explained in the preceding pages. The following comments are intended to clarify the remaining items.

1. Procedure Following

Fixed or Branched--In a fixed procedure each step is the same each time the task is performed, regardless of the outcome of any previous steps. In a branched procedure the step performed at one or more points in the procedure depends upon the outcome of a previous step. If we consider an operator of a piece of electronic equipment, his turn-on procedure is generally fixed, while his check and adjustment procedure is usually branched. The results of each check determine the adjustments to be made and may determine the subsequent checks to be made. The fact that the procedure is identical each time when the equipment is in perfect adjustment does not make it a fixed procedure.

Enter a check mark beside the word "fixed" or the word "branched" and answer the questions to the right of your check.

Number of Steps and Maximum Number of Steps--A fixed procedure has a fixed number of steps but the number of steps in a branched procedure can vary, depending upon the outcome of some of the steps. Some of the branches may be longer than others. For fixed procedures you will indicate the number of steps, but for branched procedures you

will record the maximum number of steps. The maximum number of steps refers to the longest path through the procedure, in terms of steps, from the beginning to the end of the procedure.

In arriving at these figures, keep in mind that a step generally involves a single control manipulation or a single display reading. Written "step-by-step" procedures that you may refer to may not be broken down this finely. One "step" in a written check procedure, for example, may be "Turn on the system." This "step" may include twenty steps, according to our definition. When you try to get this information from an informant, it will be necessary for you to make clear to him what you mean by "step," or you may get a very erroneous impression.

Number of SB Steps and Number of Possible SB Steps--SB means Specialized Behaviors. SB steps are steps that the trainees who will be learning the task cannot be expected to be able to perform without any training on this task. They are the steps which will require special attention during training. Some SB steps may be very quickly learned, such as reading a meter with an unusual scale. Once the scale is explained to the trainee, he can read the meter. Other SB steps may require extensive practice, such as making fine discriminations about aspects of a scope pattern in a maintenance procedure.

If the procedure is branched, you will record the number of possible steps which are SB. This figure refers to the entire procedure and not to any specific path through the procedure (such as the longest path). Your informant should consider all of the steps that could possibly be performed within this procedure and estimate the number of these which can be called Specialized Behaviors.

Describe SB Steps--The information needed about SB steps is what makes them specialized, that is, why are they not familiar to the average input trainee. Do they include tricky discriminations, particularly rapid responses, knowledge of unfamiliar terms or other skills and knowledges not likely to be in the behavior repertoire of the trainee?

NAVTRADEVCEEN 1218-4

Do not include any statements that the trainees will have to learn the names, appearance, and locations of controls, displays, or other items of equipment. This is always true, so there is no point in saying it about every task individually.

For some procedures it will be most informative to give an overall picture of the general character of the specialized steps. In others it will be better to describe some of the steps individually. The description which conveys the most accurate and complete picture is always the best description.

2. Continuous Perceptual-Motor Activity

Type--Check which kind. Guiding a vehicle can be done either from inside the vehicle or remotely, as with certain kinds of missiles. A remote manipulator may be artificial hands for handling "hot" materials, a crane, or other remotely operated handling devices. Keeping cursor on target may mean aiming a rifle at a running infantryman, keeping crosshairs on a blip on a scope, or visual tracking with a theodolite. If it seems best, simply write in what the activity is, rather than checking one of the types.

Displays and Controls--Check which are used.

Control-Display Relationship--What happens to the controlled object (crosshairs, missile, etc.) when the controls are moved? The control-display relationship in most tracking tasks can be characterized under the three headings: Position, rate, or acceleration control. A few tasks, such as controlling the pitch of a helicopter or the depth of a submarine, may involve control-display relationships of a higher order. Higher order relationships should be indicated beside the word "other" on the form. Lag and backlash are factors which introduce a delay between the instant the control is activated and the instant the display starts to react. Both can make the task more difficult and

their presence should be noted. Backlash refers to free play in the control. Lag has to do with the rate of signal transmission between control and display or reaction delays inherent in the display.

Error Tolerance or Accuracy Required--In some cases you may be able to determine a quantitative requirement, such as "must place lifted object within one inch of surveyed spot." In other cases, the requirements may be much less clear-cut, like "must be on target 80% of time." In this case, find out what "on target" means. How far off the center is still "on target?" Try to obtain a definition of required limits of accuracy, as well as the proportion of time this level of accuracy must be achieved.

3. Monitoring

Display--Indicate the way in which the monitor gets his information--the type of display to which he must pay attention.

Relevant Attribute--Check the attribute or event which will cause a detection response. If the operator is watching a radar scope, you will indicate in this item whether he is instructed to respond when a previously stationary blip starts to move, when a new blip first appears on the screen, or when a blip on the screen starts to change in size or shape.

Object or Signal to be Monitored--Whenever one is monitoring, he is looking for an object or signal which has certain "relevant attributes." Notice that each item under "Relevant Attribute" ends with the words "object or signal." Whatever these words represent in this particular task is the information entered in the item "Object or signal to be monitored."

Suppose an operator is watching a radar scope in order to detect the entrance of moving targets into radar range. You would check "scope" under "display," "appearance of object of signal" under "relevant

NAVTRADEVCEEN 1218-4

attribute," and you would write "moving target blip" under "object or signal to be monitored." You would not check "movement of object or signal" because the operator was instructed to react when a moving target appears and not when a target which is present starts to move.

Estimated Frequency of Events--How many of the watched-for events will occur per minute, per hour, per watch, per shift? How often will the detection response typically occur?

Search Area--Is he watching a whole 10" scope or only one quadrant of a scope? Is he to scan 180 degrees off the starboard side of a ship? The search area may be stated in square inches or square feet or in terms of degrees. If the operator is monitoring only auditory signals, this item does not apply. Do not enter such information as the range of the operator's radar set under this item.

Are Events Easy to Detect?--Answer "yes" or "no."

How Should Detection Be Made?--If you have answered "no" to the above question, state why the detection is difficult and state, as best you can, how the monitor discriminates between an event which calls for a detection response and one which does not.

4. Communicating

Media and Special Knowledge Requirements--These items are self-explanatory.

5. Decision Making and Problem Solving

There are three general classes of procedures by which decisions are made and problems are solved:

- a. When an operator considers only one of several available alternative courses of action because of a rule-

of-thumb, special knowledge or experience, or memory of what action has proven successful in the past, he is making a decision, so long as he could have chosen to do something else or to do nothing about the situation. He does not evaluate alternative courses of action because he judges the present situation to be sufficiently similar to one in which a certain course of action has proven to be consistently successful.

- b. For certain decisions or problems, the operator has a set of standards or criteria in mind which define an acceptable solution. He considers one alternative action or solution at a time until he finds one which is "good enough" by his set of criteria. He then implements that alternative.
- c. A third way of making decisions is sometimes possible. If the decision maker knows most of the possible alternatives, he can select a set of reasonable alternatives and evaluate each one against all others. The one that comes out best in terms of his criteria is the one he will adopt and implement.

In the first class of decision making and problem solving, the operator makes a "snap" decision without evaluating alternatives. In the second class, he looks for a solution which is satisfactory until he finds one. In the third class, he compares a full set of reasonable alternatives and picks the best one. The three classes of decision making may be illustrated by the following example. Consider a troubleshooter working on a piece of electronic equipment, who has concluded on the basis of the symptom pattern that the fault lies in one of the tubes. He must now decide which tube to replace. If he replaces one without testing it because that tube has caused the most trouble in the past, this is a decision procedure of Type a. If he puts one tube in the tester at a time until one looks bad to him, this is a

Type b decision procedure. He does not test all of the tubes unless the bad tube happens to be the last one he chooses to test, his standards of rejection are too low, or the tester is not working well. Using Type c decision procedure, he would test all the tubes and write down or remember the results of each test. He would then replace the tube that got the worst set of readings.

Indicate the type of decision making or problem solving which is prevalent in the current task and list the items of kinds of information which enter into the making of these decisions or the solving of these problems.

F. Recapitulation and a Look Forward

Training Situation Analysis is performed in five stages. You have read about System Familiarization and the Task Analysis Method. In Section II you have learned how to gain an orientation to the training problem, the system structure and flow, and the equipment which is involved. Section III described the method for delineating the task attributes relevant to making fundamental decisions about training and training devices. When you have described all of the tasks in a system in terms of the data called for by TAM, you have completed the TAM phase of TSA. You are then ready to evaluate the functional training requirements of the system. The Functional Training Requirements (FTR) stage of TSA is the stage in which basic decisions are made about the gross features of the ultimate training program. These decisions are made on the basis of the information gathered in TAM. TAM represents the current best estimate of the body of information required to make these decisions. It was devised to obtain all of the information, and to omit none of the information, required to enable the TSA team to state the general attributes of an optimal training program for any given system.

The process of translating task descriptions into functional training requirements has been analyzed, in a preliminary fashion, during the development of TAM. However, an explicit, step-by-step procedure has not as yet been devised for the FTR stage of TSA. A person who is fairly sophisticated in both the methodology of TAM and in the planning of training programs should be able to use the TAM task descriptions to derive functional training requirements for a system. Until the process whereby these decisions are made is stated explicitly, however, the training solution adopted for any given system will be partially based upon the judgment of the "expert" making the decisions. The writing of a procedure for weighting and combining the TAM data in order to derive the functional training requirements is seen to be the next step in the development of TSA.

The next section of this report (Section IV) will describe the Training Analysis Procedure (TAP). TAP is a process whereby a training priority is assigned to each task, on the basis of the cost and the potential gain in performance attributable to training. In developing a solution to the training problem, the training situation analyst aims to maximize the benefit to system performance resulting from training and to ensure the most efficient expenditure of funds. TAP enables him to consider the cost of accomplishing each proportional improvement in system performance. The task associated with the greatest potential improvement per training dollar is selected for training first. Assuming that training devices have been purchased for training the first task, the analyst searches for the task which offers the next largest performance improvement per dollar. The training device system is thus constructed, task by task, until a budgetary limit is reached. When the funds allocated for training devices are limited, TAP enables the analyst to specify the training program which would effect the greatest gain in system performance for the available amount of money.

SECTION IV*

GUIDELINES FOR

TRAINING ANALYSIS PROCEDURE (TAP)

A. Introduction to TAP

1. A Definition of TAP

Training Analysis Procedure (TAP) is a technique of system analysis which provides a ranking of tasks within a system in terms of the payoff of task training (as reflected by improved system operation) per training equipment dollar expended.

The basic philosophy of the method is that in every system there are tasks which, with training, contribute more or less significantly to the achievement of system goals. It rests with the training situation analyst to determine which tasks, any or all, should be trained, and to what benefit in system performance. The method also recognizes that a selection of tasks for training may be constrained by budgetary limitations, and, therefore, it may be necessary to place priorities on tasks to be trained.

The method examines each task in the system in its relationship to system goals and to other tasks in the system. It enables the analyst to determine, for each task, and for combinations of tasks, the improvement in system performance as a result of training.

2. The Term "System" as Used in TAP

TAP is a method of system analysis. A system is traditionally

* This Section was originally written by C. E. Van Albert, G. G. Jeantheau, J. T. Gorby, and J. A. Parrish and published as NAVTRADEVCEEN 1169-2. The present authors have made a few alterations in this Section, for which the original authors should not be held responsible. The most extensive changes are in the treatment of Mixed Systems.

defined as "... a group of things, i.e., men and equipment, organized to achieve a state or purpose." In the application of TAP, it is important that the system to be analyzed meet this definition. The system under consideration must have a clearly definable output. This output may be in terms of targets killed, missiles fired, information provided, buoys set, ships deployed, etc., but it must be definable.

One essential feature of TAP is that it considers task training only insofar as it influences system output. Thus, this output must be measurable. In this technique training on individual tasks is only important if it improves system performance.

3. Task Criticality

The theoretical foundations of TAP require that some attention be given to the notion of task "criticality." One assumption underlying TAP is that all tasks identified for analysis are critical to system operation, in the sense that task failure results in system failure. However, it is recognized that tasks may vary in their relationship to system success or failure. It is further recognized that there are degrees of system performance degradation that may be caused by poor performance of a task. Although TAP does not accommodate "degrees of criticality"--a task is either critical to system operation or it is not--considerable latitude is permitted in applying the requirement that only critical tasks be included in the analysis. The rule of thumb to be applied is as follows: If any errors which can abort system operation can occur, however unlikely such errors may be or however unlikely it may be that such errors would abort the system operation, the task may be termed critical and should be included in the analysis.

4. Performance Estimation

The TAP technique assesses the effects of training on individual tasks and relates these effects to system performance. In order to make this assessment, performance on the task before and after training

must be estimated. The estimates used in this analysis are time to perform the task, the rate at which the task is performed, and accuracy of performance on the task. Thus, the method requires the analyst to obtain evaluations of operator performance in terms of both time and accuracy for both trained and untrained operators.

The following definitions are used in developing performance data in TAP:

Time Estimates.--Time estimates are made in terms of the time required to perform a task once.

Rate Estimates.--The estimate of the rate of task performance is the reciprocal of the time estimate.

Accuracy Estimates.--Estimates of accuracy are made in terms of the likelihood that the operator will perform the task correctly, i.e., how many times out of 100 attempts will the task be performed correctly.

The Repetitive Task.--A distinction must be made between non-repetitive tasks and repetitive tasks. Nonrepetitive tasks are tasks which are performed once, and the system operates on the output or product of the performance, regardless of its quality. For example, when a radar tracking operator reports a course, bearing, and speed for a target, the system proceeds on the basis of this report even though it may be in error. Repetitive tasks are those which must be repeated until the performance is satisfactory, in order for the system sequence to continue. This type of task may be illustrated by a fire control radar operator who must lock onto a target before the system may continue. If the operator fails to lock on or loses lock on, he must repeat the necessary procedures until his performance is successful.

For nonrepetitive tasks the accuracy estimate is the probability that the task will be completed successfully (according to whatever criteria are applicable to the task in question), the time estimate is the time to perform the task once, and the rate estimate is the reciprocal of the time estimate. For a repetitive task the accuracy estimate is always 1.0, since by definition the task is repeated until performance is successful. For repetitive tasks it is necessary to calculate expected time or expected rate, which are figures based on both the time to perform the task once and the probability that a given attempt will be successful, on the average. Procedures for calculating expected time and rate are presented later.

The Monitoring Task.--Many systems include operator functions which may be called "monitoring" activities. These activities have been identified in the TAM stage of TSA. In the performance of such a task, the operator does not have an "output" in the usual sense--he is monitoring for the occurrence of some event or the achievement of some condition. This activity may be performed for long periods of time--possibly for many system operational cycles--before the event or condition occurs. The monitoring task, then, does not lend itself to the estimation of time and accuracy obtained for output-producing tasks. In TAP, the monitoring activity is not considered part of the task, for the purposes of estimating time and accuracy. However, this does not mean that a task containing monitoring behavior needs to be excluded from TAP. What has to be excluded is the part of the task which comes before the event-to-be-detected occurs. Time and accuracy estimates must be obtained for the period between the occurrence of the event-to-be-detected and the terminal event of the task. For example, in a missile system, an operator may be monitoring for missile launch malfunctions. In the performance of this task, essentially he does nothing until a missile or launch malfunction occurs. However, when either occurs, he (1) detects the presence of the malfunction, (2) diagnoses its cause, and (3) corrects the condition or switches to nonmalfunctioning equipment. Time and accuracy estimates are assigned to these latter response activities, rather than to the monitoring aspect of the task.

Untrained Performance.--Untrained performance, as the term is used here, refers to the entering level of performance of the operator. "Untrained" means untrained with respect to the subject system. Whatever the newly assigned or inexperienced operator brings to the task in terms of prior training, inherent skill, or prior related experience is considered as part of his response repertoire. In this connection one must know the characteristics of the newly assigned personnel in the system--the personnel who will undergo the training. Are they drawn directly from boot camp or are they senior personnel transferring from a different but related system? In either case, the performance capability of the newly assigned man in the subject system is the untrained performance.

Trained Performance.--Trained performance refers to the level of performance in the subject system achieved as a result of whatever training is indicated for the subject system.

It should be pointed out that the validity of the results obtained in TAP analysis rests in large measure on the precision of the performance estimates which, in turn, depends on the effectiveness with which the previous stages of TSA have been carried out. Estimates cannot be made properly without a great deal of prior research about the system, the tasks involved, and the operator performance required for the tasks. Estimates should be made carefully and rigorously--not by simple speculation. They should be guided by the broad outlines of the ultimate training program provided by the Functional Training Requirements stage of TSA.

A practical discussion of how these estimates are obtained, including the possible pitfalls, limitations, and difficulties, is given later in this section.

B. The Selection of Tasks for the Training Environment

1. The Effects of Training

TAP uses several computational models, according to the characteristics of the system being analyzed. This portion of the guidelines provides an overview of the models used and identifies situations appropriate to the application of each of the models.

• Figure of Merit (FOM)

Utilizing the time and accuracy estimates for untrained and trained performance, a measure of effectiveness is developed which relates the training provided for each task to improvements in system performance. This measure is termed Figure of Merit (FOM). It expresses the percentage improvement in system performance as a result of training on individual tasks.

For purposes of applying TAP, systems are classified as Rate Systems, Fixed Sequence Systems, or Mixed Systems. The models presented in the following sections are models for computing the FOM for systems in these different classifications. In these models the following notation is used for the terms discussed thus far in this handbook. This notation will be used in the following sections as the computational models are presented. Additional notation will be presented as required.

t_{iu} = Time estimate for untrained performance on the
ith task.

t_{it} = Time estimate for trained performance on the ith
task.

NAVTRADEVCEEN 1218-4

P_{iu} = Probability of successful performance for the untrained operator on the i th task.

P_{it} = Probability of successful performance for the trained operator on the i th task.

r_{iu} = Rate at which the i th task is performed by the untrained operator.

r_{it} = Rate at which the i th task is performed by the trained operator.

Note: Rate is computed by taking the reciprocal of the sum of time estimates for all tasks, i.e., $r_{iu} = \frac{1}{t_{iu}}$, $r_{it} = \frac{1}{t_{it}}$.

a. Rate Systems

The distinguishing characteristic of rate systems is the independence of task performances from the system cycle, such that all tasks may be repeated at any time after they are completed. An example of this type is a missile system in which the initial event in system operation is the detection of a target, and the last event is the firing of a missile. In such a system, the detection operator is free to detect another target before the first target is fired upon; in fact, immediately after the detection of the first target. Procedurally, the method examines only one system cycle, but within that one cycle tasks may cycle a number of times, i.e., may be performed at some "rate." A pure rate system is one in which all tasks in the system are, in this manner, independent of the system cycle.

Since tasks are performed at some "rate," the system can be viewed as cycling at some rate rather than cycling in a given amount of time. System performance can be expressed in terms of system rate.

In rate systems the determinant of system rate is the task with the slowest rate. The system cannot operate at a rate greater than that of its slowest task. Rate system performance may be improved in both accuracy and rate with training. The following expression which incorporates the rate feature represents the figure of merit for rate and accuracy:

$$FOM_{R\&A} = \left[\frac{P_{it}}{P_{iu}} \cdot \frac{r_{it}}{r_{iu}} - 1 \right] \times 100 \quad (1)$$

where: $FOM_{R\&A}$ = Figure of merit for rate and accuracy.

$\frac{P_{it}}{P_{iu}}$ = Ratio of trained and untrained accuracy estimates.

$\frac{r_{it}}{r_{iu}}$ = Ratio of rates for trained and untrained performance.

The Bottleneck Task--As noted above, a rate system cannot operate at a rate greater than that of its slowest task. If all of the tasks in a system must be performed once in order to produce a system output, and if all tasks may be repeated as soon as they are completed, then after some number of system cycles all the other tasks will have been completed at the time the slowest task is begun. At this point, the system rate equals the rate of performance of the slowest task. The slowest task creates a "bottleneck" in system operation. Improvements in system rate can only be achieved by improving the rate of the bottleneck task.

Formula (1) given above applies only to the bottleneck task. Training on tasks other than the bottleneck task can yield improvements in system accuracy only. FOM's computed for tasks other than the bottleneck task are for accuracy improvements only:

$$FOM_{A \text{ only}} = \frac{P_{it}}{P_{iu}} - 1 \quad \times 100 \quad (2)$$

b. Fixed Sequence Systems

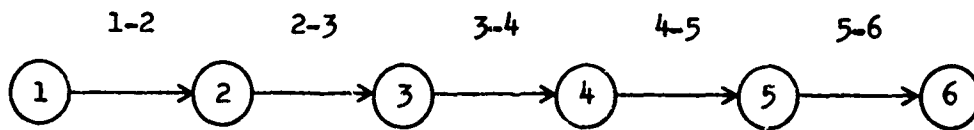
The definitive feature of the fixed sequence system is the existence of a sequential dependency between tasks such that no task in the system can be started until the previous task in the sequence has been completed, and the first task in the system cannot be repeated until the last task in the system has been completed. Thus, given a system with tasks 1 through n, each task must be done in order and the first task must wait for the completion of the nth task before it is performed again. A buoy-setting system is an example of this type. All of the tasks must be performed in the correct order and, if the first task is "steam to location" and the last task is "set buoy," clearly the system will not steam to a new location until the previous buoy is set.

Improvements in system performance in fixed sequence systems are in terms of system accuracy and system operating time. System operating time is the sum of individual task times along the Critical System Time Path (CSTP). Thus, the maximum time it will take for the system to operate is the amount of time it takes all the operators on the CSTP to perform their tasks at their untrained level of performance. The notation used for this term is:

$$\text{System operating time} = \Sigma t_{iu}$$

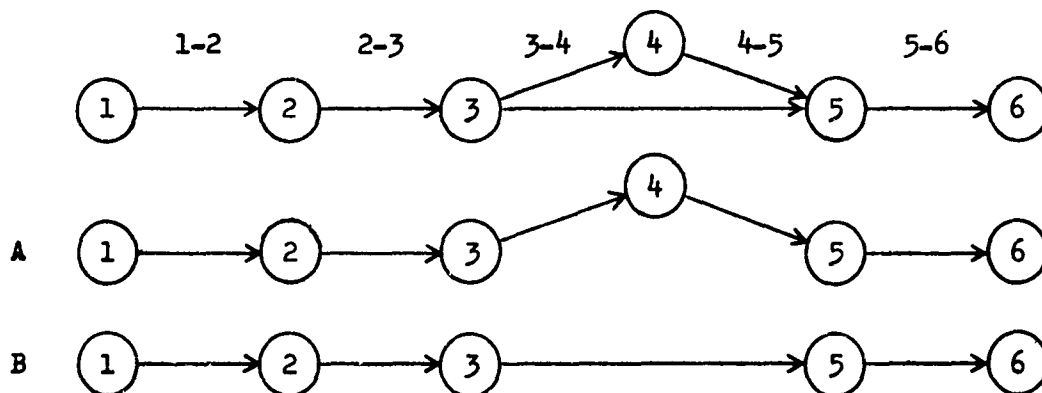
Critical System Time Path (CSTP)--In computing the system operating time, one must recognize that a system may have various "paths," or alternative channels of activity sequence. This concept may be demonstrated by diagramming the system as a network in which tasks are represented by line segments which link a sequence of events, represented by circled figures. Consider a system with the following characteristics:

NAVTRADEVGEN 1218-4



This is a single-path system in which the sequence of tasks is 1-2, 2-3, 3-4, 4-5, 5-6. Untrained system operating time is expressed as Σt_{iu} , and for this system is simply the summation of the untrained time estimates for all tasks, 1-2 through 5-6.

However, consider a system of the following type:



In this case, at event 3, two subsequent tasks are performed simultaneously forming a multiple-path system. The two paths are: A, which includes tasks 1-2, 2-3, 3-4, 4-5, 5-6; and B, which includes tasks 1-2, 2-3, 3-5, 5-6. Each path has a system untrained operating time (Σt_{iu}). System operating time is determined by the path with the greater Σt_{iu} .

The system cannot operate in less time than it takes to complete the longest path. This path is called the Critical System Time Path. Since the system operating time is bounded by the CSTP, improvement in fixed sequence system performance time can only be achieved by improvement in tasks on the CSTP. The formulation used for computing system improvement in this case is:*

* Derivations of this formula and others appear in NAVTRADEVGEN 1169-1 Training Analysis Procedures, Volume I, Theoretical Development.

$$FOM_{T\&A} = \left[\frac{\frac{P_{it}}{P_{iu}} \Sigma t_{iu}}{\Sigma t_{iu} - t_{iu} + t_{it}} - 1 \right] \times 100 \quad (3)$$

where: $FOM_{T\&A}$ = Figure of merit (percentage system improvement with training) for time and accuracy.

$\frac{P_{it}}{P_{iu}}$ = Ratio of accuracy estimates for trained and untrained task performance of the i th task.

Σt_{iu} = CSTP path time, system untrained operating time.

Tasks Not on the CSTP--In considering the $FOM_{T\&A}$, it should be recognized that, because of the characteristics of fixed sequence systems, this formulation applies only to tasks lying on the critical path (CSTP). Since, by definition, the system cannot cycle in less time than the time of the CSTP, training on tasks which do not lie on the CSTP cannot yield improvements in system time. Therefore, FOM's computed for tasks on paths other than the CSTP must reflect this limitation. These FOM's are expressed in terms of potential system improvement in accuracy only:

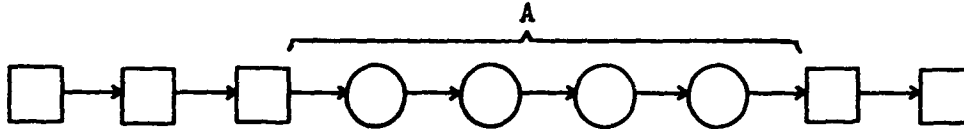
$$FOM_{A \text{ only}} = \left[\frac{P_{it}}{P_{iu}} - 1 \right] \times 100 \quad (2)$$

c. Mixed Systems

Most systems do not correspond precisely to the definitions given above for either rate or fixed sequence systems. The most commonly found systems are combinations of several groups of tasks, some of which cycle as fixed sequences and some of which cycle individually and independently of other tasks. These systems are called mixed systems.

Mixed systems are primarily rate systems in which there are blocks of tasks related as fixed sequences. The sequences may

include any number of tasks. Each sequence cycles independently of the remainder of the system. Such a system is diagrammed below.



Rectangular symbols denote events which link two tasks (or system entities) that are related in rate fashion. A rate-type task is shown with a rectangle at the beginning and the end of the task. Circular symbols represent events which link tasks into a fixed sequence. If a circle appears at either end or at both ends of a task line, this shows that the task is part of a fixed sequence. Whenever a task cannot be repeated until some later task in the system is completed, these two tasks and all tasks between them compose a fixed sequence segment of a system.

In this diagram, the fixed sequence of five tasks denoted by A occurs in what is basically a rate network. As with pure rate systems, it is necessary to determine the rate of all of the system entities in mixed systems, considering all rate-type tasks and the CSTP's of all fixed sequence segments as system entities. The sequence A is viewed in the same manner as a task in a rate system. It has a rate of performance (r_{seq}). If this rate is slower than that of any other system entity (rate-type task, in the present case), the system rate can be improved by increasing the r_{seq} for A. Since all of the tasks in the CSTP of a fixed sequence segment are sequentially dependent, the trained and untrained rates for that system entity are given by:

$$r_{u_{seq}} = \frac{1}{t_{1u} + t_{2u} + t_{3u} + \dots + t_{nu}} \quad \text{or} \quad \frac{1}{\sum t_{iu} \text{ seq}} \quad (4)$$

where:

$r_{u\text{seq}}$ = The sequence rate when all tasks are untrained.

$\Sigma t_{iu\text{seq}}$ = The sum of untrained time estimates for all tasks in the sequence.

Similarly,

$$r_{t\text{seq}} = \frac{1}{\Sigma t_{it\text{seq}}} \quad (5)$$

where:

$r_{t\text{seq}}$ = The sequence rate when all tasks in the sequence are trained.

$\Sigma t_{it\text{seq}}$ = The sum of trained time estimates for all tasks in the sequence.

If it is found that $r_{u\text{seq}}$ for sequence A is smaller than the rate for any rate-type task, it may be said that this CSTP is the "critical entity" for the system. If the rate of performance of A is improved, system rate can be improved also. In determining the effects on system performance of training on the tasks along the CSTP, that is, in computing FOM's for these tasks, the rate and accuracy formula is applied because A is the "critical entity" of the system.

$$FOM_{R\&A} = \left[\frac{P_{it}}{P_{iu}} \cdot \frac{r_{it}}{r_{iu}} - 1 \right] \times 100 \quad (1)$$

In applying this formula to the CSTP tasks, r_{it} is given by:

$$r_{it} = \frac{1}{t_{it} + t_{1u} + t_{2u} + \dots + t_{nu}} \quad (6)$$

and:

$$r_{iu} = r_{u_{seq}}$$

where:

r_{iu} = The sequence rate before training the i th task in the sequence.

r_{it} = The sequence rate after training the i th task in the sequence.

t_{it} = The trained time estimate for the i th task.

$t_{1u} \dots t_{nu}$ = The untrained time estimates for all tasks in the sequence other than the i th task.

d. The Repetitive Task

In the formulas presented up to this point, the terms used for task times are for nonrepetitive tasks. However, as noted previously, the task time for repetitive tasks must reflect the number of attempts required to achieve successful performance or, in other terms, the probability of success on any given attempt. The task time for repetitive tasks is the expected time to perform, given as:

$$t'_{iu} = \frac{t_{iu_{rep}}}{P_{iu_{rep}}}, \text{ and for trained time, } t'_{it} = \frac{t_{it_{rep}}}{P_{it_{rep}}}$$

where: t'_{iu}, t'_{it} = Expected time to perform, before and after training.

$t_{iu_{rep}}$ = Untrained time per given attempt.

$t_{it_{rep}}$ = Trained time per given attempt.

$P_{iu_{rep}}$ = Untrained probability of success per given attempt.

$P_{it_{rep}}$ = Trained probability of success per given attempt.

Thus, when computing FOM's for repetitive tasks, the task time used is the computed expected time for the task. Similarly, when computing both Σt_{iu} and Σt_{it} for each path in the system, the expected times are used for repetitive tasks.

e. Time-Bound Systems

In devising the theory which underlies TAP, it was found convenient to define the time period during which the system is to be operated. This time has been called Tau (T). This operating period can be governed by actions or physical factors external to the system. This might be the case, for example, in a surface-to-air missile system where the operating time is governed by the time targets are within range of the system. On the other hand, for certain systems, Tau can be arbitrarily stated as any time which is long compared to the time required by a single system operation. This would be the case, for example, for an industrial production system. The measure of improvement of such a system would be the increase in the number of finished

products produced in a given time period (i.e., Tau) which could be an eight-hour shift, a forty-hour week, etc.

Tau may be derived from an operational specification or calculated from a knowledge of the operational environment. For example, if an AAW system has a radar with a 100-mile detection range, and the enemy has an estimated weapon release range of 40 miles, the system must be able to respond (complete a system cycle) within the time it takes the enemy to travel the 60-mile allowable engagement range. If the estimated average enemy speed is 600 knots, this time (Tau) is 6.0 minutes.

If system operating time is determined by factors external to the system, it must be established initially that the system can complete at least one operation during the allowed operating time. If, before training, the system cannot operate once during Tau, it is time bound, and training emphasis must be placed on those tasks which will reduce system operating time.

To determine the system's ability to respond within the limits set by Tau, the untrained system operating time (one system cycle) is computed.

When $\Sigma t_{iu} > T$, it must be determined whether this is a training problem at all. If $\Sigma t_{it} < T$, then training can reduce system operating time to within operating limits. In this case, training should be directed solely to reducing operator time until a system operating time less than T is achieved. The model used is given as:

$$FOM_{T \text{ only}} = \left[\frac{\Sigma t_{iu}}{\Sigma t_{iu} - t_{iu} + t_{it}} - 1 \right] \times 100 \quad (7)$$

If the system cannot operate within Tau, and the trained system time also exceeds Tau, then it is not a training problem. It

is a problem of system design, personnel selection, or some other area which is not influenced by training.

2. The Effects of Cost on the Selection of Tasks for Training

The TAP procedure provides for the systematic examination of cost factors involved in the development of training device requirements. The incorporation of cost data into this analysis is an important and necessary step to develop properly a ranking of tasks in the order of their benefit to system performance per training dollar.

The basic inputs to this step in the procedure are estimates of equipment costs for training of each task identified in the system. It is not within the scope or purpose of this section to outline the procedures involved in estimating equipment costs. The purpose of the following description is to show the nature of the estimates required and the way in which they are utilized in this method.

It should be pointed out that the cost considerations discussed in this section do not purport to be an all-inclusive list of factors involved in cost estimation. They are intended to acquaint the reader unfamiliar with this area with the major items of interest in the application of TAP.

Since this handbook is directed toward equipment development, the cost estimation discussed in this section is equipment oriented. However, TAP permits an identification of tasks which may be trained without incurring training device costs. Such tasks are included in the analysis, and the expected improvement with training on these tasks is incorporated in the final results. These tasks are referred to as "zero cost items."

The required cost estimates should be made by people who are expert in this field--not by speculation. The results of TAP are particularly sensitive to the cost input, and the estimates should be made with great care and precision.

. Developing Costs Per Task

For each task, a cost estimate is made which includes hardware costs and additional costs that would be spent on equipment for the total number to be procured. The cost estimate answers the question, "If I were going to train on this task and this task only, what would it cost?" For each task, the equipment required to train the task is established, and cost estimates are based on these stated requirements. The establishment of the functional requirements of the training equipment for each task is properly the concern of the earlier stages of TSA (TAM and FTR)--it is not a part of TAP. The requirements developed in the Functional Training Requirements stage of TSA serve as an input to this step in TAP.

The equipment required to train a task should be grouped into component hardware units. A component unit is a distinguishable, functional part of a trainer which may be procured as a unit. For example, a radar simulator, a synthetic target generator, or an analog computer for an OFT can be considered component units.

Obviously, the determination of equipment required for training on each task is a crucial step in this analysis. For many tasks, there will be alternative techniques for simulation, or different concepts depending on level of training desired, integration with other part-task trainers, etc. For example, one frequently encountered problem will be the choice of analog versus digital simulation. For individual task trainers, a likely choice will be analog equipment--for large, complex system trainers, digital equipment is more appropriate. The TAP method conceptually builds large complex training systems by collecting part-task trainers in the order of highest payoff per task. This would appear to present a fundamental obstacle to applying the technique. The apparent inconsistency is overcome simply by estimating costs for individual tasks and also by obtaining costs for logical groups of tasks which, when integrated into larger training device

NAVTRADEVGEN 1218-4

complexes, would call for a different manner of simulation. With such data in hand, the problem becomes a straightforward matter of substitution at the proper point in the iterative process of the analysis.

In this way, the method actually permits a more meaningful evaluation of the alternatives involved in designing the training system.

It should be noted, in establishing the equipment required to train, that performance estimates obtained for each task imply a certain kind of training. Different methods of training with different training devices may yield significant differences in performance. The particular training environment on which the cost estimates are based should be the same environment for which performance estimates were derived.

. Supplementary Costs

In addition to the hardware costs indicated for the equipment recommended for training, the supplementary costs for such training must also be included in estimating the cost per task. These costs will include the costs incurred in presenting the training course, as well as the costs involved in designing new training equipment and keeping it "on the air." A fuller discussion of estimating supplementary costs is given on page 105.

. Common Equipment Requirements

The TAP procedures also take into account commonality of equipment requirements between tasks. In many systems, a number of separately identified tasks may be trained with the same equipment or portions of the same equipment. On each successive iteration (see pages 130 to 131), the equipment requirements of the remaining tasks are examined against those of the tasks selected for training on previous iterations to determine whether common equipment requirements

exist. When such commonalities occur, the consequent cost reductions are effected--reductions which result from "buying" equipment or component units on previous iterations.

3. The FOM/COST Ratio--A Summary of TAP Procedures

The effects of task training and the effects of cost have been formulated into a general procedure for examining the entire system at the task level and evaluating system training requirements.

Four essential steps are required in the treatment of each task:

- a. Estimates of performance, trained and untrained, are made.
- b. An FOM is computed.
- c. Estimates of cost are made.
- d. An FOM/cost ratio is computed.

As a result of performing these operations on each task in the system, it is possible to single out the task which offers the greatest potential benefit to system performance per training dollar. This task is identified by having the highest FOM/cost ratio.

Steps b, c, and d are repeated. On each iteration the task with the highest FOM/cost ratio is selected for training. Each time a task is selected, its trained time estimates are substituted for the untrained time estimates on the next iteration. Thus, on each iteration the representation of the system reflects training on all tasks selected on previous iterations. In this manner we conceptually "build a training device system."

Costs and percentage improvement (FOM) are cumulated after each iteration. Throughout the series of iterations, cost relationships are utilized. Frequently, the equipment required to train one task may also partially fulfill the requirements for another task. The TAP procedures insure that, in such cases, cost reductions are reflected in the tasks that have common equipment requirements. The end product of the iterative procedure is a ranking of tasks in the system in order of their trained potential for system improvement at minimum cost.

C. Diagramming the Network and Obtaining TAP Data

1. The TAP Network

The purpose of the TAP network is to depict the interrelationships and interdependencies among the tasks in a system, with specific reference to the application of TAP. In later steps in the method, the computation of FOM's for each task will be based on the nature of the task and its relationship to others. For this purpose, it has been found useful to diagram the system operation in the form of a network.

In this format, certain points in system operation can be defined as events. Each event is the beginning or end point of an activity or task. In charting the system as a network, lines represent activities or tasks and their intersections represent events (see Figure 9). The events are numbered sequentially, and tasks are referred to by the event numbers they link.

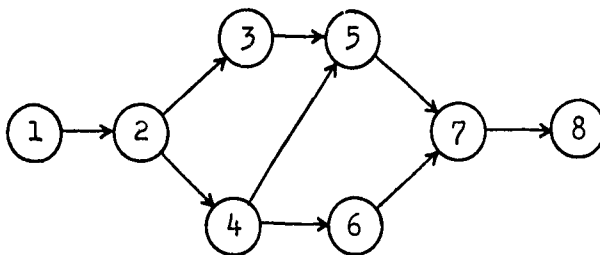


Figure 9. Multipath Fixed Sequence System

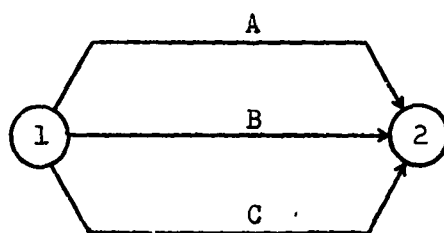
This diagram is intended to show that the system operates in the following manner. Task 1-2 initiates system operation, and when this task is completed both tasks 2-3 and 2-4 can commence. Task 3-5 can start as soon as task 2-3 is completed. Similarly, both tasks 4-5 and 4-6 can start when task 2-4 is completed. However, task 5-7 cannot commence until both task 3-5 and task 4-5 have been completed. In other words, task 5-7 requires inputs from both task 3-5 and task 4-5. This is also the case for task 7-8, which cannot start until both task 5-7 and task 6-7 have been completed. This system is to be considered as a fixed sequence system if (and only if) task 1-2 cannot start until task 7-8 has been completed.

For convenience in distinguishing between rate systems and fixed sequence systems, circles are used to show the events in a fixed sequence system and rectangles represent events which link two tasks (or system entities) that are related in rate fashion. A rate-type task is shown with a rectangle at the beginning and the end of the task. Circular symbols represent events which link tasks into a fixed sequence. If a circle is drawn at either end or at both ends of a task line, this shows that the task is part of a fixed-sequence segment of the mixed system.

Problems in Diagramming

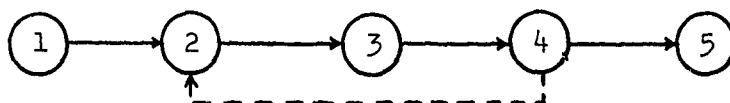
There are occasionally system configurations where it is necessary to depict several parallel tasks which begin with the same event and end with the same event. This causes difficulty because the TAP procedure calls for each task to be identified by a unique pair of numbers which represent the initial and terminal events of the task. If several tasks have the same initial and terminal events, they cannot be differentiated in the usual way. The procedure for circumventing this difficulty is to add a letter suffix to the identifying event numbers. For example, if three operators perform three simultaneous tasks, and

the events which define the start and end point of each task are the same, this portion of the system may be drawn as follows:



and these three tasks will be identified as 1-2A, 1-2B, and 1-2C, throughout the remainder of the TAP analysis.

A second problem in diagramming systems arises when one encounters a task which appears to have two terminal events. This happens most often when a task is repetitive or is the last task of a repetitive sequence of tasks (see p. 171). One of the terminal events is typically the initial event of the next system task. The others cause the task or repetitive sequence to recycle. The only event that should be shown in the TAP network is the event which permits the system cycle to continue. The events which cause the task or sequence to recycle must be ignored. However, the fact that the sequence or task is repetitive should be indicated by drawing a dotted line with an arrow from the terminal event of the repetitive task or sequence to the event which marks the beginning of the repetition, as shown below.



. Realistic System Complexity

As a caution to the reader, it should be pointed out that the fictitious examples used in this section have been created expressly for the exposition of the procedures used in TAP. For this reason, the examples used are purposely abbreviated from what may be expected in some systems. The reader should recognize that for some large systems the TAP network may be much more complex than those shown

for the systems used here. The network for a large data processing system is shown below to illustrate the order of complexity that might be expected (see Figure 10).

System Operating Modes

Most systems have several modes of operation. A single system may have several missions. For example, a shipboard missile system may operate in both an antiair warfare (AAW) mode and a shore bombardment mode. Or, a carrier aircraft may fly an ECM mission, a bombing strike mission, an air intercept mission, or an amphibious support mission. Further, most systems have a "normal" operating mode and a casualty or back-up mode. Treat these situations as follows:

(1) In charting systems for use with TAP, establish a primary mission if possible, as in the case of an AAW weapon which may also be used for shore bombardment. If a primary mission cannot be clearly established, separate networks must be prepared and separate analyses must be conducted for each mission. The carrier aircraft cited above is an example.

(2) In system networks, diagram the normal operating sequence. If the casualty mode involves major changes in operating procedures, communication links, and personnel, or the use of completely different subsystems, prepare a separate network based on the casualty which introduces such changes. If the casualty mode involves simply switching to redundant equipments, to other but identical consoles, or transferring the target entirely to another weapon system, indicate these contingency actions at the appropriate points in the normal sequence network.

The guiding principle in diagramming systems for TAP is that the representation of the system should include all tasks which are to be considered for training. In many systems this will mean creating a fictitious operation sequence. For example, a system may include several monitoring tasks where, in each case, the operator is monitoring

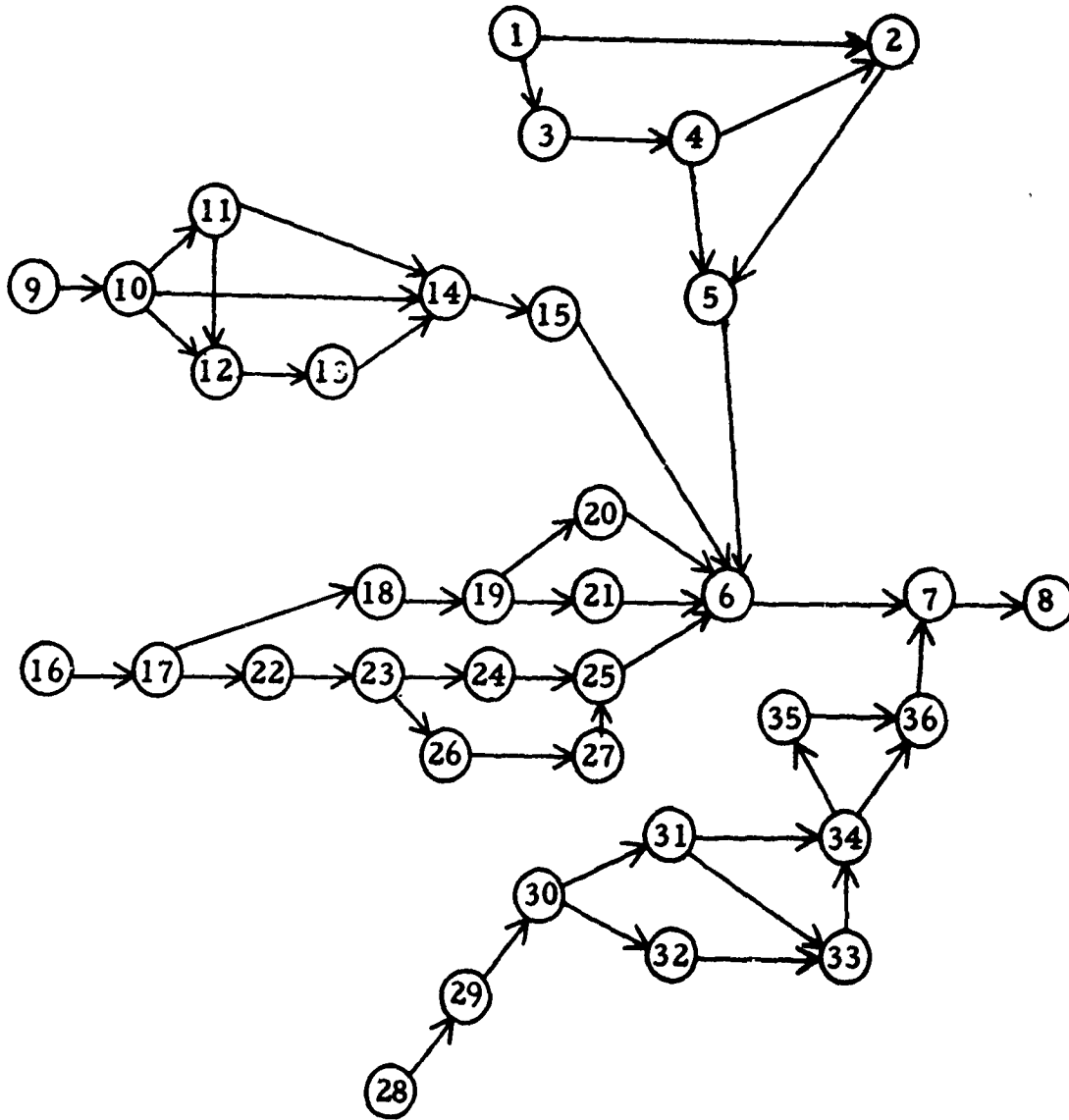


Figure 10. Complex System Network

for some casualty or contingency situation. Treatment (2) above calls for an indication of the contingency actions at the appropriate points in the normal sequence network. It is highly unlikely that all major contingencies would occur in a single operational sequence. However, this is the representation of the system which should be used, one which contains all the major contingencies at the appropriate points.

2. Data Collection

TAP is best performed by an interdisciplinary team of analysts rather than by a single individual. For example, a team might be composed of: (1) a psychologist with background in training, performance measurement, and systems, and with experience in interviewing; (2) an engineer with experience in systems, training devices, and cost estimation; and (3) an individual with some operational experience in the system under study, and, preferably, a familiarity with the training problems in the subject system. This variety of backgrounds will aid in developing a more efficient approach to the data collection process and to the analysis itself.

TAP is simply a method of organizing data about systems, about tasks, and about training. It does not create data; it does not replace good judgment and experience. The results of the analysis are no more valid than the accuracy of the data permits. It is incumbent upon the analyst, therefore, to obtain the most accurate data possible.

The following sections present some insights gained by the authors during the development of the method as to the most effective techniques for obtaining the necessary information for TAP.

Practical Methods of Collecting Performance Data

Sources of Estimates--Barring the truly unique technological breakthrough, most new systems are improvements or advancements

over previous, existing systems. These new systems embody many sub-systems (and tasks) which, functionally, are not unlike others already in existence. Under this assumption, then, the sources for the collection of human performance data in new systems become clear. For each task in a new system one must ask the following questions:

Is this task or function represented in some existing system, either identically, or very closely?

If the task is present in another system, are operational data available? In the lead bureau? The system contractor?

Can the data be obtained through interviews with operating personnel? Is there a training installation already in existence for this type of task?

Are training data available? Can training personnel be interviewed? Does the psychological literature contain research or performance data on this type of task?

If the task cannot be related to tasks in existing systems, it rests with the training analyst(s) to make expert judgments of time and accuracy, with and without practice.

Interviewing--The perennial problem of the task analyst is that most often he finds himself an intruder in the working day of either operating personnel, system engineers, or training personnel. This is a necessary evil in the collection of current, valid data. TAP imposes an additional difficulty in the data collection process.

Most of the personnel noted above (operating personnel, engineers, etc.) will be reluctant initially to provide performance

estimates in the terms required by TAP. They do not think of the tasks they deal with in terms of precise times-to-perform and even less in terms of probability of successful performance. Therefore, it is important to convey the point that only estimates are solicited, not hard, cold facts.

When seeking performance estimates for TAP, first make clear the distinction between trained and untrained operators. Untrained performance is the performance of an operator who is procured through the present training and assignment channels and who represents the level of the person likely to be assigned to the task in the operational system. For example, the man assigned to a submarine sonar system is a Class A school graduate and has been to submarine school. This level of prior background represents the "untrained" operator for this system. Similarly, senior decision makers in a new, complex system will probably be transferees who have performed similar functions in the system's less sophisticated predecessors. On the other hand, some tasks in the new system may be performed by trainees assigned directly from boot camp. Some judgment must be made as to what prior experience and training newly assigned operators can be expected to have. Operating personnel or training personnel are excellent sources of this information. Define the scope of the training system under study and solicit the opinions of these personnel as to the expected prior backgrounds of newly assigned operators.

Trained performance is the performance of an operator who has received practice on the training device proposed for the task by the analyst. When these estimates are made, the analyst is saying, in effect, "If the operator is given practice on the device we shall propose, his performance on this task will improve to this extent." For the purpose of inquiry, it is best to refer to the trained operator in generic terms. "What performance would you expect from a man who is fully trained?" is perhaps the most effective approach. If this is interpreted by the informant to include some on-the-job training in

addition to the more formal training, no harm is done so long as a similar amount of on-the-job training is assumed for all of the other tasks.

In soliciting this information, it is particularly important to establish the criteria of trained performance. The conditions under which the task must be performed must be specified. In fact, the range of possible conditions which might occur in the operational environment should be determined.

For example, trained performance of a radar operator can be stated simply in terms of ability to detect targets or track targets on the radar scope. In some situations, this definition would suffice. However, in complex weapon systems, the trained operator may be expected to read through jamming, track as many as eight targets simultaneously, track through noise, sea return, and other forms of signal degradation. These characteristics of the environment are important to the specification of trained performance for the purpose of soliciting estimates and determining the equipment required to train.

Estimates of time refer to the estimated average time-to-perform by a typical operator. In most systems it will be convenient to express these estimates in seconds although this is not a requirement. However, time estimates for all tasks in the system must be in the same units. In many cases, a careful examination of the task in proper terms will yield fairly precise estimates of performance. For example, time estimates for tasks involving the use of radar scopes will be dependent upon a standard antenna rotation rate for the radar(s). Judgements can be made in terms of the number of sweeps required to complete the task. If it is established that a search radar has a normal operating rotation rate of 5 rpm, it might be judged that it would take an untrained operator 3 sweeps to detect a target, or 36 seconds. A trained operator might take only 2 sweeps to detect, or 24 seconds.

In fact, in systems which operate on radar data, the time to complete many of the system tasks can be related to the sweep rate of the radar. Among these are establishing a true track, identifying and/or evaluating a target, and obtaining auxiliary data on a target (raid size, height, etc.).

For verbal reporting tasks, simply looking at a watch while making a report of representative content will yield accurate estimates of time. For example, an ECM operator is required to make a "racket report" for detected transmissions. The content of the report is in accordance with specific procedure. A standard representative time can be established for making this report with a few actual reporting trials.

If the respondent is reluctant to provide a time estimate, the analyst should attempt to bracket the time involved within a range of times. First, solicit a "ball park figure." "Does it take 15 minutes?" "More?" "Less?" "Does it take more than 5 minutes?" "Does 7 minutes sound about right?" Successive attempts should be made to refine the estimate once an initial figure has been given.

It is also of great benefit to have the respondent review the steps involved in the task several times; to go through the task mentally while he is developing his estimate. This procedure serves two purposes. First, it insures that there is agreement as to what is involved in performing the task. Second, it forces the respondent to think carefully about the task rather than to provide a hasty (and possibly careless) response and to dismiss the subject too quickly.

Estimates of accuracy are stated in terms of the probability of satisfactory performance by the operator. In making this judgment, the question may be asked as "How many times in 100 performances will the task outcome or product be satisfactory--with practice--without practice?"

The analyst should expect to encounter even greater reluctance in soliciting this type of information. The types of errors which can be made and the conditions which could precipitate such errors should be explored with the interviewee. Again, this forces him to think through the task and gives a greater likelihood of a valid response.

A Caution--There may occasionally be system tasks which the average input trainee would not be able to perform without considerable task-specific training. When such a task is encountered, the respondent would be justified in saying that the untrained time for the task is infinite and the untrained probability of correct performance is zero. However, the analyst should not allow the informant to use this as a device for evading a difficult judgment. If the average input trainee could perform this task after a brief orientation as to his duties, the format used in communications, the names and functions of various pieces of equipment, or some general information of this sort, then a realistic estimate of the performance level of the typical trainee who has had this sort of orientation should be obtained. Most tasks require a short briefing before they can be performed by an untrained person. Such a briefing should be assumed in obtaining untrained performance estimates.

Practical Methods of Collecting Cost Data

For each task a cost estimate is made which includes hardware costs and additional costs that would be spent on equipment for the total number to be procured. The cost estimate answers the question, "If I were going to train on this task and this task only, what would it cost?" The equipment required to train the task must be established for each task, and cost estimates are based on these stated requirements.

The results of TAP are very sensitive to the cost data used in the analysis. Since this accuracy requirement does exist, cost estimation should be done by people with experience in this work.

Estimates should not be made by speculation. The equipment required to train a task should be grouped into component hardware units. A component unit is a distinguishable, functional part of a trainer which may be procured as a unit. For example, a radar simulator, a synthetic target generator, or an analog computer for an OFT can be considered component units. The list should include alternative techniques where indicated. If the analyst is familiar with a designated piece of existing equipment which meets the requirement, the equipment should be so specified. Hardware costs for each task are organized in tabular form, itemized according to component hardware units and costs associated with these units. The form of this table is shown on page 124.

If an existing unit would meet the requirements with modifications, this fact should be specified. If the training requirement cannot be met with existing equipment, the functional characteristics of the required unit must be specified to the extent necessary to make an accurate cost estimate.

In the TAP analysis, a single cost figure is used for each task. The cost figure represents the total cost of all the units required for training on that task. In addition to the cost of fabricating the equipment recommended for training, there are two classes of supplementary costs which should be factored into the estimate of cost per task. One has to do with the supplementary costs associated with developing, operating, and maintaining the training devices. The other relates to the supplementary costs incurred in presenting the training course. The supplementary training device costs will include such items as R&D costs for items which do not presently exist, field service, spare parts, and documentation costs. The supplementary training course costs will include the cost of training time, instructors, classroom space, text materials, etc.

A strong effort should be made to obtain direct estimates of as many as possible of these supplementary costs for each task. However, the overriding consideration is that the cost estimates for providing

training should be based on the same set of factors for every task. If this requirement is not met, the comparison of FOM/cost ratios across tasks, a fundamental step in TAP, becomes somewhat meaningless. If estimates on all relevant cost factors for all tasks are not available, this does not mean that some factors should be entirely omitted from consideration. The effect of basing a task's training cost figure upon an incomplete set of cost variables will be an underestimation of any budgetary limitations which may exist. Some allowance must be made for the costs which will be incurred but which cannot be estimated for each task in advance.

If supplementary costs are computed by multiplying the hardware cost for each task by some constant percentage, an accurate figure for the total cost of the training program may be obtained (to the extent that the percentage correctly represents the average relationship between equipment costs and supplementary costs). However, this procedure is not recommended. When supplementary costs are computed in such a manner, they contribute nothing to the final ranking of tasks in terms of system improvement per cost of training.

The recommended procedure for computing total task training cost is as follows:

1. List all cost variables which will contribute to the overall cost of the training program.
2. Select the cost factors on which estimates can be made for each task (both hardware and supplementary costs).
3. Obtain the above set of cost estimates for every task.
4. Estimate the average percentage of the cost of training which is contributed by variables for which cost estimates cannot be obtained on every task.

5. Subtract this percentage from 100% and divide it by the result of the subtraction.
6. For each task, multiply the resulting decimal fraction by the total of the costs which can be estimated.
7. For each task, add this product to the total of the estimated costs to obtain the total task training cost.

Number of Units for Procurement--Although the present procedures for TAP are based on the assumption that the device to be developed is a single, complex trainer, many such training devices are composites of a number of part-task trainers. These collective units are often composed of many identical modules such as radar simulators or target position generators. In some cases, the number of identical modules is great enough to effect a savings in cost by buying in quantity. In systems where a number of different tasks require the same module, but in different numbers, a schedule of costs per unit as a function of quantity should be obtained (see page 122).

Common Cost Items--The TAP technique conceptually "builds" a training device, task by task. However, as each task is added to the training curriculum, the total cost of training is rarely increased by the full cost of training which has been estimated for the added task. With the incorporation of every new task (after the first one), the analyst must reevaluate the cost of adding the new task to the curriculum, in view of the cost items which the new task has in common with tasks already chosen. He must ask: "What will be the cost of adding training on this task to the training program which was determined by the previous iterations?" This reexamination will involve the common supplementary cost requirements, as well as the common hardware requirements.

Most large training devices have an instructor's console associated with the actual simulation equipment. Many have a single

computer which generates the training environment. These units are common to all tasks in the system. However, the features of the instructor's console or the size or configuration of the computer may vary as a function of the number and kind of tasks incorporated in these units at each stage of the analysis. The specific requirements of each task with regard to such units must be determined and the consequent costs must be developed.

Soliciting Cost Estimates--In gathering cost data, it is particularly important to continually stress to the engineer that each task is being costed separately. He must be cautioned not to think in terms of "whole" devices but rather in terms of functional units. When several tasks may be incorporated into a single subsystem trainer, and such a unit is being costed as an alternative, the costs of "integrating" several units must also be included.

D. Rate Systems - Procedures

Rate systems are defined as systems in which any task in the system cycle may be repeated before the system has completed its cycle. Thus, during any one system cycle, the first task, or other tasks in the system, may be performed a number of times, i.e., at some "rate." In a "pure" rate system all tasks may cycle independently of the system cycle. System rate is then determined by the task in the system with the lowest rate; the system cannot cycle at a greater rate than its slowest task. Improvement in system performance in rate systems is measured in terms of improvements in task rates as well as accuracy. This portion of the guidelines presents the procedures to be used in applying TAP to rate systems.

The procedures used in TAP fall into five distinct steps:

1. Preliminary Analysis of the System - The Network

This step involves an analysis of the system to identify the

tasks and task sequences to be considered for training. As part of this analysis the decision is made as to whether multiple missions exist and whether separate analyses will be required for the missions. The system is diagrammed as a network, and it is determined whether the rate, fixed sequence, or mixed system models apply.

2. Development of the Task Table

Within this step, performance estimates are made for both trained and untrained operators. The performance estimates are organized in tabular form and rates are computed.

3. Development of the Cost Table

For the cost table the equipment required to train each task is determined. The total costs of equipment per task are obtained and organized in tabular form.

4. Iterative Analysis

It is in this step that the data collected on performance and cost for each task are analyzed with relation to the system and to each other. An iteration table is developed in which a FOM and the FOM/cost ratios are computed for each task. These computations are carried out in an iterative manner. As a result of each successive iteration, a task or group of tasks is selected for training. After each iteration, the "trained" data for the task(s) selected are substituted for the "untrained" data, and the remainder of the system is analyzed with the previously selected tasks considered as "trained."

Common equipment requirements between tasks are noted as tasks are selected, and appropriate adjustments are made to cost data for succeeding iterations. The iterative procedure is continued until all tasks have been selected for training.

5. Results

The series of iterations described above yields a ranking of tasks in order of their benefit to system performance per dollar of equipment cost. These data are most usefully presented in a plot of estimated system improvement (FOM) as a function of cost. The data are plotted as a step function where each step represents the task(s) selected on successive iterations.

* * *

This section discusses in step-by-step detail the actual procedures used in implementing TAP for rate systems. The procedures are presented by means of a hypothetical system example--"The Corridor Penetration System." The reader should refer to Table 4 at the end of the section as each step is discussed.

Five major subsections are included in this discussion, each representing a major step in the analysis. These include:

- a. The Network--diagramming the system
- b. The Task Table--making performance estimates
- c. The Cost Table--making cost estimates
- d. The Iteration Table--computing FOM's and ratios
- e. The Table of Results--presenting the results

1. Networks

In performing the analysis on rate systems, a network diagramming technique is used similar to that described under subheading C of this section, except that square symbols are used for events rather than circles. This convention is adopted largely for later use in mixed

systems when both rate-type and fixed sequence tasks are present in a system.

To illustrate the procedures used for rate systems, the analysis of a hypothetical system is followed step by step. Consider a subsystem which might be called the Corridor Penetration System, with the following characteristics as given in this fictitious system description. (In this illustration, this extremely simple subsystem will be treated as a complete system.)

"...Based upon precise position information received from HQ Search Section, targets are located by Detection Operators (DO) #1 through #4 on repeaters of the AN/ALQ-85 radar. Upon detection, the DO interrogates the target with the INT-7 system and determines whether the target is hostile. The INT-7 system allows the operator to interrogate two targets simultaneously. Hostile targets are transferred to one of two Classification Operators located at the Mk 1 Classification Console. Hostile targets are also entered at the Corridor Penetration Status Board. Target classification is accomplished by inserting the appropriate classification code into the computer access channel and pushing the CLASSIFY button at the Mk 1 Console. Target classification is displayed to the operator on the classification panel of the console. The Mk 1 operator then transmits, via sound-powered telephone, to the Air Threat Coordinator.

"On the basis of the information received regarding target characteristics, the Air Threat Coordinator evaluates the threat of the penetration and determines the availability of defense forces at the Force Deployment Console (FDC). Available forces are then assigned by the ATC. . . "

NAVTRADEVCE 1218-4

The system described may be diagrammed as shown in Figure 11. In this figure an event, as denoted by the numbers enclosed in each square, is defined as the beginning and/or end of a specific task or activity in the system operation. The lines joining events represent tasks. The tasks are referred to by the two event numbers they link, as 1-2, 2-3 etc.

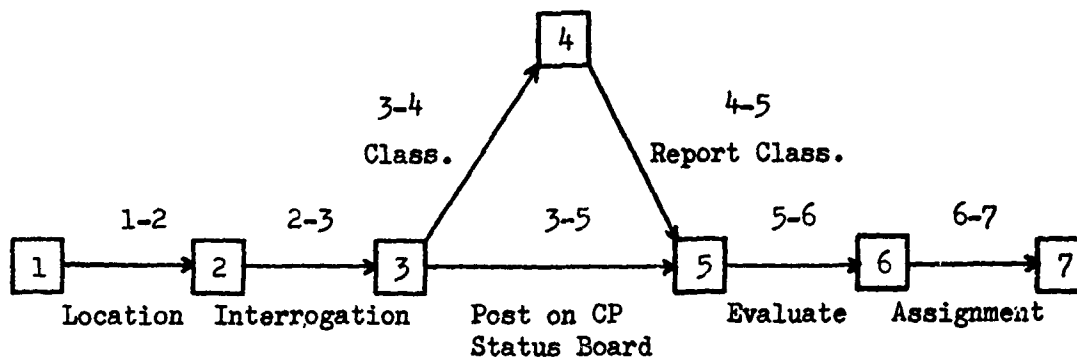


Figure 11. Corridor Penetration System Network

Note that at event 3, the completion of the interrogation task, two activities begin and take place simultaneously: 3-4, the classification task; and 3-5, the posting of targets on the CP Status Board.

The tasks identified are then collected in a list, as below:

<u>Task No.</u>	<u>Task Description (Operator)</u>
1-2	Target location (DO)
2-3	Target interrogation (DO)
3-4	Target classification (CO)
3-5	Post on CP Status Board (SB op)
4-5	Report classification (CO)

5-6	Evaluate threat and force availability (ATC)
6-7	Force assignment (ATC)

This listing of tasks is then amplified into the Task Table by the addition of performance estimates for each task.

2. Task Table

For each task shown in the list above, estimates are made for probability of accurate performance by untrained operators (p_u), probability of accurate performance by trained operators (p_t), time-to-perform for untrained operators (t_u), and time-to-perform for trained operators (t_t). The task table takes the form shown in Table 2, page 118.

Computation of Rate--For the rate system, an additional step is required in the preparation of the task table. The rate at which each task may be accomplished by both trained and untrained operators must be computed.

Rate is defined simply as:*

$$r_{iu} = \frac{1}{t_{iu}}$$

where: r_{iu} = rate of the untrained task

t_{iu} = time estimate for the untrained task performance

* In systems where the task in question is performed in parallel, i.e.,

an identical function performed by more than one operator, $r_{iu} = \frac{n_i}{t_{iu}}$

and $r_{it} = \frac{n_i}{t_{it}}$, where n = the number of operators performing the task.

Similarly,

$$r_{it} = \frac{1}{t_{it}}$$

where: r_{it} = rate of the trained task

t_{it} = time estimate for the trained task performance

For this hypothetical system, suppose the following sources of information are available:

- a. A preliminary system operation manual.
- b. System design engineers.
- c. A training installation which trains on tasks 1-2, 2-3, and 3-4.

Utilizing these sources the following information is derived:

Task 1-2 Target Location

Accuracy Estimates--Through interviews with system design personnel it is determined that the nature of the target location task is such that the operator will never fail to locate the target, given the coordinate information from the HQ Search Section. Therefore, for both the trained and untrained operators we assign a probability of 1.0. These figures are entered in the task table under p_u and p_t .

Time Estimates--The benefit to be derived from training in this task, however, is a reduction in the time to pinpoint a target on the CRT display. The time for location is cut in half with training.

Interviews with training personnel at the 1-2 Training Installation indicate that the normal sweep rate for the AN/ALQ-85 Radar is 10 rpm. Each sweep, then, takes 6 seconds. Untrained operators take an average of 8 sweeps to locate the reported target on the PPI. The total time is 48 seconds. Trained operators accomplish this task in 4 sweeps or 24 seconds. These entries are made in the task table for t_u and t_t , respectively.

Rates--There are four Detection Operators in this system. The rate for a single untrained operator in locating targets at 48 seconds per location is 1.25 targets per minute. Thus, four operators locate 4×1.25 targets or 5 targets per minute. This is the maximum rate in this particular function. Similarly, the trained time of 24 seconds yields an individual operator rate of 2.5 targets per minute. Four operators can process 4×2.5 targets or 10 targets per minute. These figures are entered into the table under r_u and r_t .

. Task 2-3 Target Interrogation

System documentation provides the information that target interrogation is performed using a photoelectric device which is part of the INT-7 system. Personnel at the 1-2 Training Installation, who also train on task 2-3, estimate that untrained operators will perform this function correctly 90 times out of 100 or with a .90 probability of success. Trained operators improve to the point of making only one error in 100 operations. The trained probability of success is .99. These figures are entered into the table.

Time estimates given for the interrogation function are 2 sweeps for untrained operators (12 seconds) and 1 sweep for trained operators (6 seconds). These figures are entered in the table.

It is learned from the system documentation that the INT-7 system allows each operator to interrogate two targets simultaneously. The number of targets capable of being interrogated at one

time by four operators is 8. The rate for individual untrained operators, at 12 seconds for interrogation, is 5 targets per minute. Since 8 targets can be interrogated simultaneously, the maximum output in this function is 40 targets per minute. Similarly, the rate for trained operators is 10 targets per minute and 80 targets per minute is the maximum output in this function.

• Task 3-4 Target Classification

Target classification involves the selection of an appropriate numerical code according to target type, size, and vector. Via keyset this information is entered into the computer. Training personnel indicate that learning the necessary codes and operating the keyset are factors which improve greatly with training. The obtained data indicates probabilities of .75 for untrained operators and .98 for trained operators. Times given are 15 seconds for untrained operators and 10 seconds for trained operators. Translated into rate, these figures become $r_u = 4$ targets/minute and $r_t = 6$ targets/minute for individual operators. System output in this task (since there are two operators) is $r_u = 8$ targets/minute and $r_t = 12$ targets/minute.

• Task 3-5 Post on CP Status Board

This task requires the CP status board operator to enter on the board the classification of targets, received verbally from the classification operator. Time-to-perform is not a major consideration in the task; it does not improve with training. System design personnel indicate that the average operator performs the task in 3 seconds.

However, personnel who have dealt with similar plotting board tasks in other systems indicate that accuracy of performance increases somewhat with training. The estimates they give are a decrease in errors from 5 in 100 to 1 in 100 after training. Accuracy estimates of .95 and .99 are entered accordingly in the task table.

Since only one operator performs the function (in 3 seconds), the rate for both trained and untrained performance is 20 targets per minute.

. Task 4-5 Report Classification

This task is a simple reporting task--a verbal communication by the Mk 1 operator to the Air Threat Coordinator. The classification message is given according to SOP. Sample reporting trials are timed, and the time to perform is 5 seconds. The time to report does not change with training. The likelihood of error is zero, and probability of successful performance is 1.0 for both trained and untrained operators. These data are entered in the table.

At 5 seconds per report, 2 operators can make 24 reports per minute. These rates are entered for both r_u and r_t .

. Task 5-6 Threat Evaluation

The Air Threat Coordinator position is filled by the senior officer. These individuals have many years' experience in threat evaluation. Even though the task requires a major decision, officers of this type estimate that, by transferring prior experience to the new system, they will make the correct assessment 90 times out of 100. With experience in the new system, it is estimated that only 2 incorrect decisions in 100 will be made, giving a probability of success of .98.

The time taken by the untrained man in weighting the target information against force availability is estimated at 10 seconds. With experience on the new system, it is estimated that this can be cut in half--to 5 seconds.

The 10 seconds untrained and 5 seconds trained, converted to rate, give $r_u = 6$ decisions per minute and $r_t = 12$ decisions per minute, respectively.

Task 6-7 Force Assignment

Once the decision has been made to assign forces, the implementation of the decision is simply a matter of transmitting an order. The task is performed without error by both untrained and trained men and is accomplished in 3 seconds, trained and untrained. Translated into rate, this becomes 20 orders per minute, trained and untrained.

Table 2. Corridor Penetration System - Task Table

Task	p_u	p_t	t_u	t_t	n	r_u	r_t
1-2 Target Location (DO)	1.0	1.0	48	24	4	5	10
2-3 Target Interrogation (DO)	.90	.99	12	6	8	40	80
3-4 Target Classification (CO)	.75	.98	15	10	2	8	12
3-5 Post on CP Status Board	.95	.99	3	3	1	20	20
4-5 Report Classification (CO)	1.0	1.0	5	5	2	24	24
5-6 Evaluate Threat and Force Availability (ATC)	.90	.98	10	5	1	6	12
6-7 Force Assignment (ATC)	1.0	1.0	3	3	1	20	20

The task table for rate systems is set up as shown above-- with three additional columns, for n , r_u , and r_t . The task with the lowest rate determines the system rate. This task can be termed "the bottleneck task." In this example, the bottleneck task is task 1-2 with a rate of 5 target locations per minute. The r_u and r_t values in this table were computed using the formulas shown above.

3. Cost Table

A full demonstration of the procedures used for developing costs in TAP is given in the following sections. Section a. is devoted

to a discussion of the equipment required to train each task. Section b. is a detailed statement of the cost estimates and the manner in which they are organized.

a. Corridor Penetration System - Equipment Required

. Task 1-2 Target Location

Task 1-2 is one which involves the use of a CRT display of the AN/ALQ-85 radar. A proper training environment should include a minimum of 4 simulated targets in order to permit successive locations by the 4 detection operators. To train on this task, then, an ALQ-85 radar simulator and 4 radar target generators are required. Engineers ascertained that a "Type II" power supply would be required for a trainer incorporating these units.

. Task 2-3 Target Interrogation

In task 2-3 the 4 DO's use the INT-7 device to interrogate the targets located in task 1-2. If training were to be given on only this task (interrogation), the radar and target simulation would be necessary and, in addition, some method of providing the INT-7 device. From examination of the characteristics of the INT-7 device and discussions with both system engineers and training device engineers, it is determined that: (1) the INT-7 system may not be procured for training installation, and (2) the system may be simulated with sufficient fidelity for significantly less cost than the operational system.

It is further determined that a Type II power supply would also be adequate for a device incorporating these units.

. Task 3-4 Target Classification

Operationally, the target classification is accomplished at a Mk 1 Classification Console. The console provides for the push

button entry of target information. After a detailed examination of the task, it is determined that, again in this case as in task 2-3, the necessary elements of the training environment may be provided by a simulation of the Mk 1 Classification Console. The simulation used includes the information entry capability and the essential feedback indications to the operator. This unit may be referred to as a Mk 1 C. C. Feedback Simulator. Since this unit is the only one in the device necessary to train task 3-4, a Type I power supply is deemed to be adequate by costing engineers.

. Task 3-5 Post on CP Status Board

Training for the status board operator requires only verbal inputs; it does not require any equipment other than a free communication circuit. The entry is made in the cost table "no equipment required."

. Task 4-5 Report Classification

Based on the performance estimates, no improvement is made through training. No training is considered for this task; therefore, there are no equipment requirements.

. Task 5-6 Evaluation of Threat and Force Availability

The evaluation of threat by the Air Threat Coordinator is based on verbal communication from the Classification Console Operator. The determination of force availability is accomplished at the Force Deployment Console. The determination is made that a simulation of the Force Deployment Console will provide the necessary training situation for this task. Engineers estimate that a Type I power supply would be adequate for this equipment.

NAVTRADEVGEN 1218-4

. Task 6-7 Force Assignment

No training is considered for this task.

b. Estimating Costs

The range of equipment required for all tasks is listed below:

<u>Task</u>	<u>Equipment Required</u>
1-2	ALQ-85 radar simulator, 4 radar target generators, Type II power supply
2-3	ALQ-85 radar simulator, 4 radar target generators, INT-7 simulator, Type II power supply
3-4	Mk 1 Classification Console Feedback Simulator, Type I power supply
3-5	No equipment
4-5	No training
5-6	Force Deployment Console Simulator, Type I power supply
6-7	No training

It is established that one prototype trainer will be built for the Corridor Penetration System.

NAVTRADEVCEEN 1218-4

The following cost data are obtained from engineering personnel:

- 1) The AN/ALQ-85 radar has been simulated previously--no R&D costs are incurred. The unit cost is \$45,000 per radar for less than production quantity.
- 2) A radar target generator is available as an off-the-shelf item at \$4,000 each for quantities less than six.
- 3) The required INT-7 simulator is an R&D item. Estimated unit cost, in less than production quantity, is \$1,500. R&D cost is estimated at \$3,500.
- 4) A Mk 1 C. C. Feedback Simulator is an R&D item. Estimated unit cost is \$6,000. R&D cost is estimated to be \$12,000.
- 5) A Force Deployment Console Simulator is an R&D item. The estimated unit cost is \$6,500 with an R&D cost of \$13,500.
- 6) A Type II power supply is an off-the-shelf item. Cost per unit is \$3,000.
- 7) A Type I power supply is an off-the-shelf item. Cost per unit is \$2,000.

The individual costs for equipment units are entered in the table as follows:

NAVTRADEVGEN 1218-4

Task 1-2

ALQ-85 R. S.	1 unit @ \$45K ea.	45K
Radar tgt. gen.	4 units @ 4K ea.	16K
Type II power supply	1 unit @ 3K ea.	3K
Total		64K

Task 2-3

ALQ-85 R. S.	1 unit @ \$45K ea.	45K
Radar tgt. gen.	4 units @ 4K ea.	16K
INT-7 Sim.	1 unit @ 1.5K ea.	
	+ R&D @ 3.5K	5K
Type II power supply	1 unit @ 3K ea.	3K
Total		69K

Task 3-4

Mk 1 C. C. Feedback Sim.	1 unit @ \$ 6K ea.	
	+ R&D @ 12K	18K
Type I power supply	1 unit @ 2K ea.	2K
Total		20K

Task 5-6

FDC simulator	1 unit @ \$6.5K ea.	
	+ R&D @ 13.5K	20K
Type I power supply	1 unit @ 2K ea.	2K
Total		22K

NAVTRADEVGEN 1218-4

This information is organized in the following manner to form the cost table.

Table 3. Corridor Penetration System -
Cost Table (One Installation)

Task	Equipment Required	ALQ-85	Tgt. gen.	INT-7	Mk-1	FDC	Type I P.S.	Type II P.S.	Total
1-2	ALQ-85 R.S. 4 tgt. gen. Type II P.S.	45	16				3		64
2-3	ALQ-85 R.S. 4 tgt. gen. INT-7 sim. Type II P. S.	45	16	5			3		69
3-4	Mk 1 C.C. Feedback Sim. Type I P. S.				18		2		20
3-5	No equipment necessary								
4-5	No training								
5-6	FDC sim. Type 1 P. S.				20	2			22
6-7	No training								

Note that task 3-5 is a task which can be trained, but does not require dynamic simulation. It is a zero cost item as discussed on page 90.

4. Iteration Table

The development of the iteration table demands the greatest care. Although the mathematics used is quite simple, the bookkeeping

may become involved. For this reason, frequent checks should be made of computations performed and of data entered into the table.

To follow the procedures used in working out the Corridor Penetration System example, the reader should refer to the foldout table at the end of this section (Table 4) as each step is discussed. Table 4 is the completed iteration table for the TAP application to the Corridor Penetration System.

. The Format

The form of Table 4 was developed to organize the data in the most expeditious manner for performing the necessary computations. It permits the analyst to review all computations after each iteration and to review all iterations and task selections when the table is complete.

. Table Entries

All trainable tasks (tasks for which there is expected improvement with training) are identified and one column in the table is allotted to each. The following data are entered for each task:

- a. On line 1, enter the p_u value for each task.
- b. On line 2, enter the p_t value for each task.
- c. On line 3, enter the t_u value for each task.
- d. On line 4, enter the t_t value for each task.
- e. On line 5, enter the r_u value for each task.
- f. On line 6, enter the r_t value for each task.
- g. Compute p_t/p_u for each task and enter on line 7.
- h. Compute r_t/r_u for each task and enter on line 8.

. Identification of the Bottleneck Task

The next step is to identify the bottleneck task. In rate systems, the bottleneck task is the task with the slowest

untrained rate. Thus, the lowest figure contained on line 5 of the table indicates the bottleneck task. In Table 4, the bottleneck task is task 1-2 with an untrained rate of 5 targets per minute.

. Iteration I

At this point, the table contains all the data necessary to perform the first iteration. The first step in the iterative procedure is to compute the figure of merit (FOM) for each task. FOM's are entered on line 9 of the iteration table (see Table 4).

Computation of the FOM--In rate systems, two formulae for the FOM are applicable. First, the bottleneck task is treated differently from others with higher rates. Training on only the bottleneck task can yield improvements in system rate, since system rate is determined by the bottleneck task rate. This fact is recognized in the computation of FOM's. Training on tasks other than the bottleneck task will result only in improvements in system accuracy.

Bottleneck Task - FOM--By training on the bottleneck task, system performance can be improved in both rate and accuracy. The formula for computing the estimated percentage improvement with training (FOM) is given as:*

$$FOM_{R\&A} = \left[\frac{p_t}{p_u} \cdot \frac{r_t}{r_u} - 1 \right] \times 100 \quad (1)$$

Using data directly from the rate system iteration table, the formula can be expressed as:

* The reader interested in the derivation of these formulae should refer to NAVTRADEV/CEN 1169-1, Training Analysis Procedure, Volume I, Theoretical Development.

$$FOM_{R\&A} = \left[\text{line 7} \times \text{line 8} - 1 \right] \times 100 \quad (1a)$$

Nonbottleneck Tasks - FOM--The formula for the nonbottleneck task's FOM reflects the fact that training on these tasks yields system improvement in accuracy only. It is given as:

$$FOM_{A \text{ only}} = \left[\frac{p_t}{p_u} - 1 \right] \times 100 \quad (2)$$

Using data in the iteration table, this can be expressed as:

$$FOM_{A \text{ only}} = \left[\text{line 7} - 1 \right] \times 100 \quad (2a)$$

Limitations - Partial Improvement--FOM's are computed for the critical task first. However, noncritical tasks may limit improvements in rate for the critical task. Therefore, gains in rate that may be expected by training on the critical task cannot exceed the difference in rate between the critical task and other tasks in the system. This limitation is taken into account when computing the FOM for the critical task.

The iteration table for the Corridor Penetration System shows that the critical task is task 1-2, with a rate of 5 targets per minute and an expected improvement of 10 per minute with training. Although we might expect an improvement of 5 targets per minute in task 1-2, task 5-6 has a rate of 6 targets per minute. Therefore, we can only realize an improvement in system rate to a level of 6 per minute because of the bound imposed by task 5-6.

In the computation of the FOM for task 1-2, the formula is applied:

$$FOM = \left[\frac{p_t}{p_u} \cdot \frac{r_t}{r_u} - 1 \right] \text{ or } \left[1.00 \cdot \frac{6}{5} - 1 \right] = .20$$

NAVTRADEVCEEN 1218-4

The value of 6 used for r_t represents the limiting value imposed by task 5-6. Thus, we realize only a 20 per cent improvement when, without the limitation, we would have expected 100 per cent improvement.

Cost Entries--When all FOM's have been computed and entered in the table, the cost data are entered. The total costs per task as computed in the cost table (expressed in thousands of dollars) are entered on line 10 for each task (see Table 4).

FOM/Cost Ratio--The FOM/cost ratio is the index on which the final results of a TAP application are based. This index represents the "payoff" per dollar invested in training equipment. Payoff is in terms of the greatest benefit to system performance per training dollar. The next step in the analysis is to compute the FOM/cost ratio for each task.

Selection of the First Task--After FOM/cost ratios are computed for all tasks, the first task is selected for training. The task selected for training on every iteration is the task with the highest FOM/cost ratio. This rule applies whether or not the task with the highest ratio is the bottleneck task. The highest ratio indicates the greatest benefit to system performance, whether the benefit be in rate alone, rate and accuracy, or accuracy only.

See Table 4. The zero cost task, task 3-5, has a ratio of infinity and is selected along with task 3-4 which has the highest ratio, 1.53. Zero cost tasks are always selected on the first iteration along with the first task. Zero cost tasks are indicated by the unfilled or outline symbol as contrasted with cost tasks indicated by the solid symbol.

. Iteration II

After the task with the highest FOM/cost ratio has been selected on the first iteration, it is removed from further consideration, and the remaining tasks are examined for the effects of the first selection.

The first determination to make is whether system rate has changed. In rate systems this determination is made quite simply:

- a. If the task selected for training on the previous iteration was the critical task, system rate may have changed.
- b. If the task selected on the previous iteration was not the critical task, the system rate will not have changed.

In the Corridor Penetration System, task 3-4 which was selected was not the critical task. Providing training for this task does not change system rate. Therefore, on the second iteration task 1-2 is still the critical task.

Computation of the FOM--The next step in the second iteration is to compute the FOM for each task. The procedures used in Iteration I apply. However, some rules of thumb may be noted:

- a. If the task selected in the previous iteration was a noncritical task, FOM's remain the same.
- b. If the task selected in the previous iteration was the critical task, and its r_t/r_u ratio was 1.0, FOM's remain the same.
- c. If the task selected in the previous iteration was the critical task, and its r_t/r_u ratio was greater than 1.0, recompute the FOM's.

It is particularly important to recognize when the critical task changes, that is, when a different task becomes the critical task, in order that the appropriate FOM's be used on the succeeding iteration.

Cost Changes--The TAP method recognizes and accounts for the possible common equipment requirements between tasks. It is in the second iteration that this consideration is first made. The effects of "buying equipment" for the first task selected are examined for any possible reduction in cost for tasks in succeeding iterations.

The format of the cost table (Table 3) was designed with these effects in mind. It permits the rapid recognition of cost changes from iteration to iteration.

The first step in the examination of the data for possible cost changes is to indicate the equipment units which were "bought" for the task selected on the first iteration. Before the cost data are entered for each task on the second iteration, the question must be asked "Does this task have any equipment requirements in common with the task selected on the previous iteration?" Where commonalities do exist, the cost data entered for the task is reduced by the cost of the common equipment. For example, on the first iteration of the Corridor Penetration System, tasks 3-4 and 3-5 were selected for training. Equipment for task 3-4 included the Mk 1 C. C. Feedback Simulator and two Type I power supplies. Task 5-6 also requires a Type I power supply. Note that in the second iteration, line 13 (Table 4), the cost for task 5-6 has been reduced by \$2,000, the cost of the Type I power supply.

Note the change in cost for task 2-3 between the third and fourth iterations (lines 16 and 19). Task 1-2 is selected for training on the third iteration. All of the equipment required for task 2-3 with the exception of the INT-7 simulator was "bought" for task 1-2. Thus, on the fourth iteration the cost for task 2-3 is reduced by \$64,000, the total cost of task 1-2. This left a remainder of \$5,000, the entry on line 19.

In many cases different tasks have identical equipment requirements, and when one of these tasks is selected for training, the cost for the other is reduced to zero. Consequently, with a cost of zero the FOM/cost ratio is infinity, and these tasks are the next to be selected.

Computation of the FOM/Cost Ratio--Having computed new FOM's and entered new costs, the next step is to compute new FOM/cost ratios. These ratios determine the task(s) with the next greatest benefit to system performance per training dollar. Again, the task with the highest ratio is selected, whether it is the bottleneck task or not.

5. Table of Results

The iterative procedure is continued until all tasks have been "trained" and removed from consideration. The order of tasks selected, from the first iteration to the last, constitutes the ranking of tasks in order of their benefit to system performance per training expenditure. The most effective graphic technique for presenting the results of this analysis is shown in Figure 12. This plot shows system improvement as a function of cost. The points on the curve represent the tasks selected, and they are plotted as a step function.

Results plotted in this form provide guidelines in making the following fundamental judgments about training device requirements for a system:

- a. If training is provided for all tasks in the system, what percentage of system improvement can be expected, and what will it cost?
- b. If budgetary limitations will not permit every task in the system to be trained, which tasks should be trained within the limitation, and what is the expected system improvement with this training?

NAVTRADEVCEEN 1218-4

- c. Even without budgetary limitations, are there points at which further expenditures do not yield commensurate improvement in system performance?

TAP cannot make these decisions for the analyst, but this simple graphic presentation will aid in making sound recommendations.

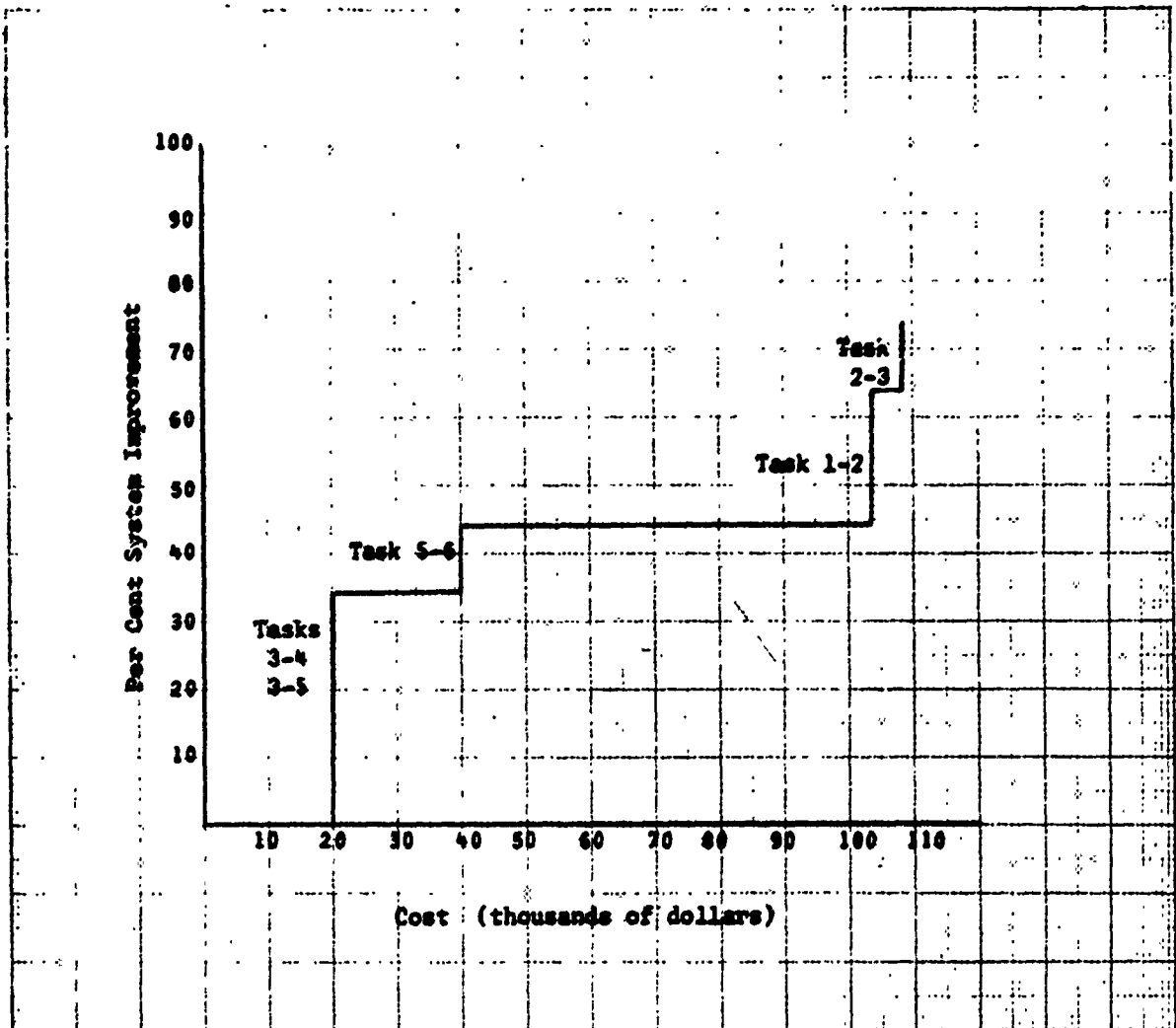


Figure 12. Corridor Penetration System--System Improvement as a Function of Cost

Table 4.

Corridor Penetration System--Iteration Table

		Tasks				
		1-2	2-3	3-4	3-5	5-6
line 1	P_u	1.0	.90	.75	.95	.90
line 2	P_t	1.0	.99	.98	.99	.98
line 3	t_u	48	12	15	3	10
line 4	t_t	24	6	10	3	5
line 5	r_u	5	40	8	20	6
line 6	r_t	10	80	12	20	12
line 7	P_t/P_u	1.000	1.100	1.306	1.042	1.088
line 8	r_t/r_u	2	2	1.5	1	2
line 9	FOM	20.0	10.0	30.6	4.2	8.8
line 10	COST	64	69	20	0	22
line 11	FOM/COST	.312	.144	1.53	*	.400
line 12	FOM	20.0	10.0	▲	△	8.8
line 13	COST	64	69			20
line 14	FOM/COST	.312	.144			.440
line 15	FOM	20.0	10.0	▲	△	▲
line 16	COST	64	69			
line 17	FOM/COST	.312	.144			
line 18	FOM	▲	10.0	▲	△	▲
line 19	COST		5			
line 20	FOM/COST		2.0			
line 21	FOM		▲	▲	△	▲
line 22	COST					
line 23	FOM/COST					

E. Fixed Sequence Systems - Procedures

A fixed sequence system is one in which no task can be repeated until the preceding task in the sequence is completed, and the system itself cannot recycle until the last task is completed. Typically, in this type of system, each task produces an output which is also the necessary input for one or more tasks. The purpose of this subsection is to illustrate the procedures for handling fixed sequence systems. A simplified hypothetical system will be carried through the five TAP steps. The reader should refer to the foldout (Table 7) at the end of this subsection as each step is discussed.

1. Network

Consider a simple example in which the following is a segment of a system description for the hypothetical "Tracer System." (This segment will serve throughout this section as the basis for demonstrating the development of the necessary data, the processing of the data, and the results which may be derived from this analytic technique.)

"...The target is then entered at Display Console (DC) #3. The DC #3 operator applies a tracer to the target. When the DC #3 operator determines that the tracer is secure, he signals READY TO TRANSFER (RTT) with a foot switch to the DC #4 operator and notifies the Integration Console operator via intercom. Upon receipt of the RTT signal, the DC #4 operator sets up the appropriate quadrant for transfer and signals READY TO RECEIVE (RTR) via a foot switch. The Integration Console operator evaluates all four quadrants for possible conflict. When conditions are clear, he pushes the transfer button. The target is then transferred to DC #4..."

NAVTRADEVCEEN 1218-4

From this descriptive passage we can identify ten tasks involving three operators. This operation would be diagrammed as below in Figure 13, Tracer System Network.

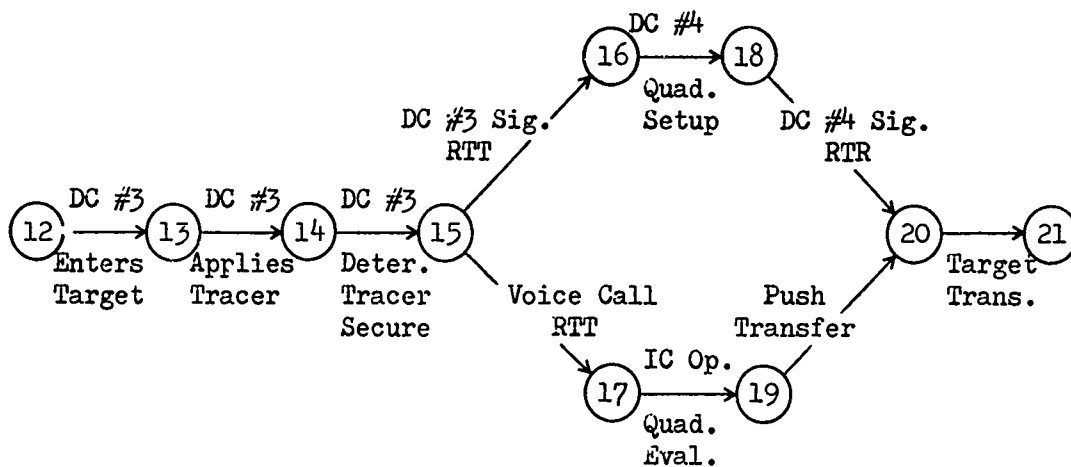


Figure 13. Tracer System Network

An "event," as depicted by circled numbers in the figure above, is defined as the beginning and/or end of a specific task or activity in the system operation. The lines joining events represent tasks. The tasks are denoted by the two event numbers which they link, as 13-14, 15-16, etc. It should be noted at event 15 that information is transmitted to two different stations. In the network then, two paths emerge which represent the parallel or simultaneous activities of two operators. Also note that activity 20-21 (an automatic or machine task) cannot take place until tasks 18-20 and 19-20 are both complete. When analyzing a system, it is important to note such conditional activities. It is also important to include machine activities in the network when they provide necessary continuity between operator activities.

2. Task Table

The tasks identified are collected in a list, as below:

<u>Task #</u>	<u>Task Description</u>
12-13	DC #3 enters target
13-14	DC #3 applies "tracer"
14-15	DC #3 determines "tracer secure"
15-16	DC #3 signals RTT to DC #4
15-17	DC #3 voice call RTT to IC operator
16-18	DC #4 quadrant setup
17-19	IC operator quadrant evaluation
18-20	DC #4 signals RTR
19-20	IC operator pushes TRANSFER
20-21	Target transfers to DC #4

The next step in the development of the task table is to make estimates of performance for trained and untrained operators for each task.

For each task in the list shown, estimates are made for probability of accurate performance by untrained operators (p_u), probability of accurate performance by trained operators (p_t), time-to-perform for untrained operators (t_u), and time-to-perform for trained operators (t_t). The task table takes the form shown in Table 5.

For this hypothetical system, suppose the following sources of information are available:

- a. A preliminary system operation manual.
- b. System design engineers.
- c. A training installation which trains on tasks 12-13, 13-14, 14-15.

NAVTRADEVCEEN 1218-4

Table 5

Task Table--Tracer System

Task		p_u		p_t	t_u	t_t
12-13	.85,	1.0	.95,	1.0	7	6
13-14		.95		.99	6	6
14-15		.75		.98	12	12
15-16		1.0		1.0	2	2
15-17		1.0		1.0	2	2
16-18		.85		.99	30	18
17-19		.95		.99	10	5
18-20		1.0		1.0	2	2
19-20		1.0		1.0	2	2
20-21					2	2

Task 12-13 - A Repetitive Task

From the system description and interviews with system design personnel, it is determined that task 12-13 involves the detection of a target on a radar scope and the pressing of an ENTRY button on the console.

Accuracy Estimates--The task is a repetitive task in that it must be repeated until performed successfully--task 13-14 cannot take place until task 12-13 is completed. Accordingly, there will be two accuracy estimates for task 12-13. The first estimate is the probability of detection on any given attempt at the task. In the case of radar detection, this is the probability that the operator will detect the target on any given sweep. Here, suppose we learn from the system description that the operator will have prior information on the general location of the signal on the scope as a result of previous processing by the system. This fact would increase any estimate made for probability of detection without advance information. For the untrained operator, then, we assign a "given attempt" probability of .85 which says, in effect, we estimate that the operator will fail to detect the target 15 times out of 100 sweeps. In addition, we confirm this estimate by interviews with personnel at the 12-13 Training Installation.

In repetitive tasks, however, it is also true (by definition) that after a number of attempts the operator will successfully complete the task--giving a probability of 1.0. This is the probability of successful performance for that task.

These estimates (.85, 1.0) are entered in the table as the p_u values for task 12-13. After discussion with personnel at the 12-13 Training Installation, it is determined that with practice an operator's probability of detection on a given sweep is .95. His task probability is, again, 1.0. These figures are entered in the table as the p_t values for task 12-13.

Time Estimates--Time estimates for repetitive tasks follow the same general thinking as accuracy estimates. For task 12-13, we must first estimate the amount of time required to perform the task if it were performed satisfactorily on any given attempt. Since we have estimated $p_u = .85$ on one sweep, obviously this task can be performed in one sweep. From the system design engineers, we establish a standard

NAVTRADEVGEN 1218-4

antenna rotation rate of 10 rpm for the radar being used. An operator can then perform the task in 6 seconds. This is the time per given attempt. This completion time is achieved with a probability of only .85 (untrained accuracy per given attempt). We then must calculate an expected time for completion over a large number of trials. This is done by dividing the time on a given attempt by the probability of success on that attempt. In this case it is 6 seconds divided by .85, or 7 seconds. Thus, 7 seconds is the expected task completion time.

The estimated time per given attempt for the trained operator is also one sweep or 6 seconds. The expected time for a trained operator is 6 seconds divided by .95. Rounded off, this is also 6 seconds.

Thus, for the t_u and t_t values of task 12-13, we enter 7 and 6 seconds, respectively (see Table 5).

Task 13-14 - A Nonrepetitive Task

Task 13-14 is a nonrepetitive task. System information indicates that the application of the "tracer" by the DC #3 operator involves superimposing a coded symbol over the target by means of a joystick. The operator will perform the task only once, and the system will operate on whatever data are provided by this action regardless of its quality. For this reason, it is a nonrepetitive task. The system has an error tolerance for the positioning of the symbol with respect to the target. If the symbol is positioned by the operator within acceptable limits, the data provided will permit the system to function effectively in subsequent steps. If the positioning exceeds tolerable limits, the system will continue to function but will be operating on out-of-tolerance data. From the 12-13 training personnel, it is determined that novices can perform this operation within acceptable limits, 95 times out of 100. We assign a value of .95 as the p_u for task 13-14. From the same source it is further determined that, with practice, this performance improves to .99. This is the p_t value for task 13-14. These figures are entered in the table (see Table 5).

A time estimate for a nonrepetitive task is simply the time-to-perform for that task. In this case it requires an average of one sweep on the radar to accomplish symbol positioning. We establish that both trained and untrained operators will perform in 6 seconds. Entries of 6 seconds are made in the table for t_u and t_t for task 13-14.

Task 14-15

The task is described as "DC #3 operator determines tracer secure." It is learned from system designers that this task requires the operator to determine, in two sweeps, that the system has "locked on" to the target sufficiently to effect a target transfer. This involves a perceptual judgment of successive error between the target and the coded symbol on each sweep. Error tolerances are small and the judgment is precise.

Accuracy of performance for this task is enhanced significantly with practice. Training personnel indicate that new trainees make this judgment correctly only 75 times out of 100. However, with practice these judgments are made correctly with a probability of .98.

Time-to-perform in task 14-15 is determined by operating procedures--the judgment is made in two sweeps. Thus for both trained and untrained operators, times are 12 seconds (see Table 5).

Task 15-16

This task is nonrepetitive. It is a simple foot-switching operation. It has no evaluative aspects; the evaluation is made in the previous task, 14-15. The likelihood that the operator will depress the foot switch when not ready to transfer or that he will not depress it when ready is negligible. Therefore, accuracy for both trained and untrained operators is 1.0. Similarly, the time taken to perform this task cannot be improved with practice. It is estimated that the action takes

NAVTRADEVCEEN 1218-4

2 seconds (see Table 5). Task 15-16 is, in a sense, an "untrainable task," i.e., no improvements in performance can be gained with training (see Table 5).

- . Task 15-17

Simultaneously with task 15-16, the operator voice calls "ready to transfer" to the Integration Console operator. The same rationale as used in task 15-16 is applied to this simple reporting task. Both p_u and p_t are 1.0 and times are 2 seconds, trained and untrained.

- . Task 16-18

In task 16-18, the DC #4 operator accomplishes a setup routine for a single quadrant display involving a number of steps to prepare the equipment. In tasks of this type (setup and/or checkout sequences) the several routine steps are collected under one task title. Accuracies may vary widely depending upon the intricacy and length of the procedure. System designers indicate that task 16-18 is mainly a series of six simple button-pushing operations and one cursor-positioning step. A consensus of estimates from designers and TSA personnel gives a probability of .85 for unpracticed operators and .99 for practiced performance.

A simple check with a stop watch on several analysts going through a representative set of motions, plus some intuition with regard to the effects of training, yields time estimates of 30 seconds for t_u and 18 seconds for t_t .

- . Task 17-19

Task 17-19 is nonrepetitive. The Integration Console operator performs an evaluative function in this system. His task involves comparing coded symbols in each of four quadrant displays

and applying decision rules based upon the quantities displayed. This operator is a senior member of the processing team, and the task requires extensive experience in the area. We determined from system design personnel that the decisions made here are not unlike decisions made in this system's predecessor. The task differs only in the form of the display and the symbology employed. Further, we anticipate that the operator in task 17-19 will most likely be a transferee from the old system. In this case, it is necessary to interview operating personnel in the old system to establish realistic estimates of performance for the task.

Based on such interviews, it is determined that the counterpart task in the old system was accomplished with an accuracy of .90 untrained, and was improved to .97 with practice. However, discussions reveal that the task requirements of 17-19 are somewhat simplified by the new display form. The accuracy estimates for 17-19 are modified accordingly, and the final estimates are .95 and .99.

Time estimates derived in a similar manner are 15 seconds and 10 seconds in the old system, revised to 10 seconds and 5 seconds for 17-19.

. Task 18-20

Task 18-20 is a nonrepetitive task identical to 15-16--a simple foot-switching operation denoting completion of the previous task. The same values used for 15-16 are used for 18-20.

. Task 19-20

Task 19-20 is a nonrepetitive task--a simple button-pushing operation. Again, the same values are used as for 15-16.

Task 20-21

Task 20-21 is a "machine" task. It is accomplished by the electronic computer in the system and cannot be trained. However, it is included in the network to maintain continuity of information flow and activity sequence, and to maintain accurate system time estimates.

A time estimate is made for the target transfer denoted by 20-21 since it affects total system time. We assign a time of 2 seconds.

The entry of these figures completes the task table.

3. Cost Table

To demonstrate fully the procedures used in developing initial cost data in TAP, the Tracer System data ~~are~~ worked out in detail in the following sections. The procedures for determining cost changes in the iterative analysis are discussed under "Cost Changes," page 163. Although the determination of equipment requirements per task is not part of the TAP procedures, this step is illustrated for the Tracer System example. The purpose of this illustration is mainly to show the form in which the requirements are stated for use in TAP.

a. Equipment Required

. Task 12-13

Task 12-13 is basically a radar detection task utilizing a repeater (DC #3 console) displaying the "AN/XYZ-99" radar. The operator is never required to deal with more than one target at a time. Targets appear in range and bearing only. The equipment necessary for training operators in this particular detection task is a radar simulator for the XYZ-99; a single, range-and-bearing-only, target generator; a Type I power supply; and a GFE DC #3 console. At this point, a requirement has

NAVTRADEVCEEN 1218-4

been established for three different training device "units." In this case, the training device is intended for a shipboard installation feeding directly to existing operational units. In such instances the operational equipment is not considered in the cost analysis. If, however, the proposed device is intended for an installation where GFE would have to be procured, the costs of the necessary procurement must be included in the analysis.

Task 13-14

Task 13-14 is also performed at the DC #3 console which repeats the AN/XYZ-99 radar. This task differs from task 12-13 in that the operator must maneuver a coded symbol with respect to the target. In addition to the requirements of 12-13, a symbol or character generator is necessary.

Task 14-15

Task 14-15 is performed at DC #3 using the same display information as task 13-14. It has the same equipment requirements as task 13-14.

Task 15-16

Note in the task table (page 138) that performance on task 15-16 cannot be improved with training. Therefore, it need not be examined further. No cost estimates are made.

Task 15-17

Same as task 15-16--no estimates made.

NAVTRADEVCE 1218-4

. Task 16-18

Task 16-18 is performed at DC #4--a setup sequence which prepares the console for target transfer. During the setup sequence, the display repeats one quadrant of the AN/XYZ-99 display. In this case, in addition to a radar simulator, a feedback device is required which will provide the necessary sequence of indications to the operator as he steps through the procedure. Under "equipment required" for task 16-18, an XYZ-99 radar simulator and a "DC #4 setup simulator" are listed. A DC #4 setup simulator as required does not presently exist. Therefore, in consultation with engineers, the cost of developing the unit must be determined.

. Task 17-19

Task 17-19 is performed at the Integration Console which includes four separate, expanded displays of each quadrant of the AN/XYZ-99. The operator must evaluate as many as four targets simultaneously, all in conjunction with their coded symbols.

The equipment requirements for this task include four target generators (of the type to be used for task 12-13), an AN/XYZ-99 simulator, and either a four-channel character generator or four separate character generators. The latter choice will be made on the basis of cost and feasibility estimates by the engineers. It is also determined that the Type I power supply is satisfactory for this device.

. Task 18-20

Again, this is a task which cannot be improved with training (see Table 5). No estimates are made.

. Task 19-20

No estimates are made (see Table 5).

NAVTRADEVCEEN 1218-4

. Task 20-21

No estimates are made (see Table 5).

Having examined each task in terms of the equipment required to train that task, the next step in the development of the cost table is to obtain cost estimates and prepare an itemized cost list for the necessary equipment.

b. Estimating Costs

The range of equipment required for all tasks includes five distinct units; an AN/XYZ-99 radar simulator, a range-and-bearing-only target generator, a character generator, a DC #4 setup simulator, and a Type I power supply. These requirements are summarized in the list below.

<u>Task</u>	<u>Equipment Required</u>
12-13	XYZ-99 R.S., rb tgt. gen., Type I P.S.
13-14	XYZ-99 R.S., rb tgt. gen., Character Gen., Type I P.S.
14-15	XYZ-99 R.S., rb tgt. gen., Character Gen., Type I P.S.
15-16	No Training
15-17	No Training
16-18	XYZ-99 R.S., DC #4 setup sim., Type I P.S.

NAVTRADEVCEEN 1218-4

17-19	XYZ-99 R.S., four rb tgt. gen., four channel character gen., Type I P.S.
18-20	No Training
19-20	No Training
20-21	No Training

Cost Estimates

It is established that two trainers of this type will be built, as shore-based installations.

The following cost data are obtained from cost estimators (usually engineering personnel):

- 1) The AN/XYZ-99 radar has been simulated previously; no R & D costs are incurred. The unit cost is \$25,000 per radar for less than production quantity.
- 2) A range-and-bearing-only target generator is available as an off-the-shelf item at \$4,000 each for quantities less than 6. For quantities of 6 or more, the unit cost is \$1,250 each.
- 3) A character generator of the type required is an R&D item. Estimated unit cost, in less than production quantity, is \$1,500. R&D cost is estimated at \$3,000. A four-channel character generator is feasible and the unit cost is estimated to be \$2,500. The R&D cost is estimated at \$5,000.

NAVTRADEVCEEN 1218-4

- 4) A DC #4 setup simulator is an R&D item. The estimated cost per unit is \$800 with an R&D cost of \$1,500.
- 5) A Type I power supply is an off-the-shelf item. Cost per unit is \$1,000.

This information is organized in the following manner to form the cost table.

Table 6

Cost Table--Tracer System

Task	99 R.S.	Tgt. Gen.	Char. Gen.	DC #4 Sim.	P.S.	Hdwre. Total
12-13	50K	8K	-	-	2K	60K
13-14	50K	8K	6K	-	2K	66K
14-15	50K	8K	6K	-	2K	66K
15-16						
15-17						
16-18	50K	-	-	3.1K	2K	55.1K
17-19	50K	10K	10K	-	2K	72K
18-20						
19-20						
20-21						

NAVTRADEVCEEN 1218-4

The individual costs for equipment units are entered in the table as follows:

Task 12-13

XYZ-99 R.S.	2 units @ \$25K ea. --	50K
rb tgt. gen.	2 units @ 4K ea. --	8K
Type I P.S.	2 units @ 1K ea. --	2K
Total		60K

Task 13-14

XYZ-99 R.S.	2 units @ \$25K ea. --	50K
rb tgt. gen.	2 units @ 4K ea. --	8K
char. gen.	2 units @ 1.5K ea. plus R&D @ 3K --	6K
Type I P.S.	2 units @ 1K ea. --	2K
Total		66K

Task 14-15

Same as 13-14

Task 16-18

XYZ-99 R.S.	2 units @ \$25K ea. --	50K
DC #4 sim.	2 units @ .8K ea. plus R&D @ 1.5K --	3.1K
Type I P.S.	2 units @ 1K ea. --	2K
Total		55.1K

Task 17-19

XYZ-99 R.S.	2 units @ \$25K ea. -- 50K
rb tgt. gen.	8 units @ 1.25K -- 10K
Char. gen.	2 units @ 2.5 K ea. plus R&D @ 5K -- 10K
Type I P.S.	2 units @ 1K ea. -- 2K
Total	72K

4. Iteration Table

In order to understand precisely the steps in the iteration process, the reader is urged to refer to the iteration table worked out on page 166 at the end of the chapter as each step is described in the text. The table on page 166 represents the entire series of iterations for the Tracer System example, treated as a fixed sequence system.

. The Format

It has been found most useful to follow the iteration procedure by organizing the necessary data in a table constructed in the form shown in Table 7. This format permits the analyst to review the results from iteration to iteration in a rapid and efficient manner.

The iteration procedure is largely an exercise in simple arithmetic. However, although the method is simple, utmost care must be taken in both computing and entering data in the table. There are several reasonableness checks that can be made at various stages--and all figures should be checked after each iteration before proceeding to the next one.

. Identification of Paths

In the preparation of the iteration table, one must account for all the alternate paths in the system network, i.e., all paths must be represented in the table. Each path represents an independent sequence of activity and information flow through the system, leading to a system output. Figure 14 on page 153 illustrates paths in several different kinds of system networks.

The Tracer System has two paths (see Figure 17). Path A includes tasks 12-13, 13-14, 14-15, 15-16, 16-18, 18-20, and 20-21. Path B includes tasks 12-13, 13-14, 14-15, 15-17, 17-19, 19-20 and 20-21.

. Identification of Trainable Tasks

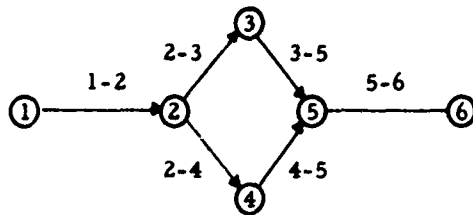
For each path identified, list the tasks in that path. In each list, indicate the "untrainable" tasks, i.e., machine tasks or tasks for which there is no expected improvement with training. In Figure 17 (page 166) these tasks are 15-16, 15-17, 18-20, 19-20, and 20-21. For each path, compute the sum of the untrained time estimates (t_u) for the "untrainable" tasks which are entered. This sum may be called "K". In Figure 17, the K for both path A and path B is 6 seconds.

For each untrainable task, indicate the untrained time estimate (t_u). In each case in Figure 17, the t_u happens to be 2 seconds.

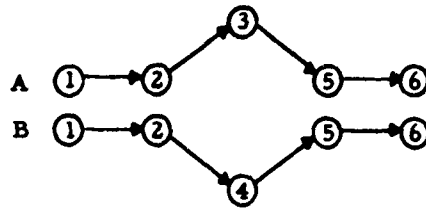
Table Entries

- a. Enter the remaining, or "trainable," tasks into the columns of the iteration table, one task per column.
Every trainable task in every path must be represented

I



Network



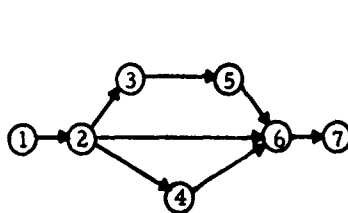
Paths

In System I shown above, two paths exist:

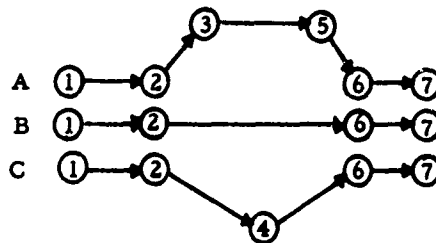
Path A - which includes tasks 1-2, 2-3, 3-5, 5-6

Path B - which includes tasks 1-2, 2-4, 4-5, 5-6

II



Network



Paths

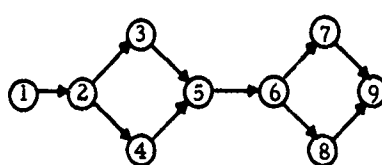
In System II, three paths exist:

Path A - including tasks 1-2, 2-3, 3-5, 5-6, 6-7

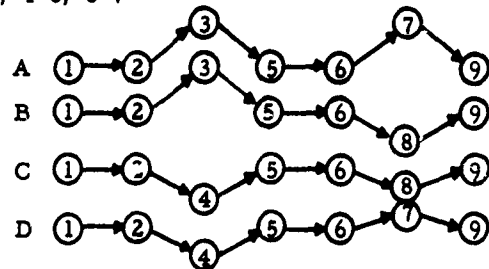
Path B - including tasks 1-2, 2-6, 6-7

Path C - including tasks 1-2, 2-4, 4-6, 6-7

III



Network



Paths

In System III, there are four paths:

Path A - 1-2, 2-3, 3-5, 5-6, 6-7, 7-9

Path B - 1-2, 2-3, 3-5, 5-6, 6-8, 8-9

Path C - 1-2, 2-4, 4-5, 5-6, 6-8, 8-9

Path D - 1-2, 2-4, 4-5, 5-6, 6-7, 7-9

Figure 14. Multiple Networks

NAVTRADEVCEEN 1218-4

in the table. Tasks which are common to several paths are entered in the task group for each path in which they occur.

- b. Label the task groups for each path A, B, etc. (if appropriate).
- c. Indicate repetitive tasks with "R" above the task number.
- d. On line 1, enter the p_u estimates for each task.
- e. On line 2, enter the p_t estimates for each task.
- f. On line 3, enter the t_u estimates for each task.
- g. On line 4, enter the t_t estimates for each task.
- h. Compute the ratio, p_t/p_u , for each task (line 2 divided by line 1). Enter these ratios on line 5.
- i. Compute the difference, $t_u - t_t$, for each task. (Line 3 minus line 4). Enter these differences on line 6, labelled Δt . Note: When computing $t_u - t_t$ for repetitive tasks, the expected time estimates should be used.
- j. For each path, compute Σt_{iu} , the sum of the untrained time estimates for all tasks in the path. This involves adding the K for the path to the sum of t_u estimates of the trainable tasks entered in the table. Thus, the Σt_{iu} for each path is the Σt_u for the untrainable tasks (K) plus the Σt_u for the trainable tasks (those entered in the table). Enter the Σt_{iu} for each path on line 7 and circle

the figure. The Σt_{iu} represents "path time." The path times in the Table 7 are 61 seconds for path A and 41 seconds for path B. Note: When computing Σt_{iu} for paths which contain repetitive tasks, the expected time estimates should be used.

. Iteration I

At this point, the table contains all the data necessary to perform the first iteration. The first step in the iterative procedure is to compute the figure of merit (FOM) for all tasks.

Computing the FOM--In fixed sequence systems, several formulae for the FOM apply:

First, tasks on the CSTEP (i.e., Critical System Time Path) are treated differently from those on non-CSTEP's. It should be remembered that the FOM is an index of system improvement as a result of training on the task. Since system operating time is limited by the critical path, i.e., the system cannot operate in less time than it takes to complete the critical path, improvements in task time can benefit system time only when the task lies on the critical path. This fundamental notion is reflected in the FOM's for CSTEP and non-CSTEP tasks.

CSTEP Tasks--By training tasks on the critical path, system performance can be improved in both time and accuracy. The formula for computing the estimated percentage improvement with training is given as:*

* For the reader interested in the derivation of these formulae, see NAVTRADEVCEEN 1169-1, Training Analysis Procedures, Volume I, Theoretical Development.

$$FOM_{T\&A} = \left[\frac{\frac{p_t}{p_u} \Sigma t_{iu}}{\Sigma t_{iu} - t_u + t_t} - 1 \right] \times 100 \quad (3)$$

where: $FOM_{T\&A}$ = Figure of merit for time and accuracy.

p_t/p_u = The ratio of accuracy estimates for trained and untrained performance.

Σt_{iu} = The sum of the time estimates for untrained performance.

t_u = The untrained time estimate for the task.

t_t = The trained time estimate for the task.

This expression can be reduced to:

$$FOM_{T\&A} = \left[\frac{\frac{p_t}{p_u} \Sigma t_{iu}}{\Sigma t_{iu} - \Delta t} - 1 \right] \times 100 \quad (3a)$$

where: $\Delta t = t_u - t_t$

For actual computation purposes, the equation may be expressed in terms directly applicable to iteration table 7:

$$FOM_{T\&A} \text{ non-rep.} = \left[\frac{\text{line 5} \times \text{line 7}}{\text{line 7} - \text{line 6}} - 1 \right] \times 100 \quad (3b)$$

Repetitive Tasks - CSTP--It should be noted that, for repetitive tasks, p_t/p_u is always 1.0 since, by definition, the task will be repeated until completed successfully. Further, Δt for repetitive tasks is the difference between expected times to perform.

With these facts at hand, equation (3a) reduces even further to equation (3c) below:

$$FOM_{T\&A \text{ rep.}} = \left[\frac{\Sigma t_{iu}}{\Sigma t_{iu} - \Delta t} - 1 \right] \times 100 \quad (3c)$$

Equation (3c) reduces to equation (3d):

$$FOM_{T\&A \text{ rep.}} = \left[\frac{\text{line 7 (path)}}{\text{line 7 (path)} - \text{line 6 (task-expected)}} - 1 \right] \times 100 \quad (3d)$$

Non-CSTP Tasks--By training tasks not on the critical path, system performance can be improved in accuracy only. The formula for computing the estimated percentage improvement with training is given as:

$$FOM_{A \text{ only}} = \left[\frac{p_t}{p_u} - 1 \right] \times 100 \quad (2)$$

For computation purposes, using the data directly from the iteration table, this equation may be expressed simply as:

$$FOM_{A \text{ only}} = \left[\text{line 5 (task)} - 1 \right] \times 100 \quad (2b)$$

This equation is the same for both repetitive and non-repetitive tasks. But obviously for repetitive tasks p_t/p_u is always 1.0 and the FOM is zero. This says, in effect, that no improvement in system performance can be expected by training repetitive tasks that are not on the critical path.

Limitations on the FOM - Partial Improvement--In actual practice, FOM's are computed for the CSTP first. In computing FOM's for the CSTP, the analyst must remember that each FOM represents the improvement in system performance that may be expected if the task is trained.

However, it should be kept in mind that the system operating time is determined by the longest path time. In this connection, the following problem can arise:

If the gain in time expected with training on a task exceeds the difference in time between the CSTP and a noncritical path, the actual gain in system time cannot exceed the difference in time between the two paths. This limitation is taken into account in computing the FOM.

Consider the following example:*

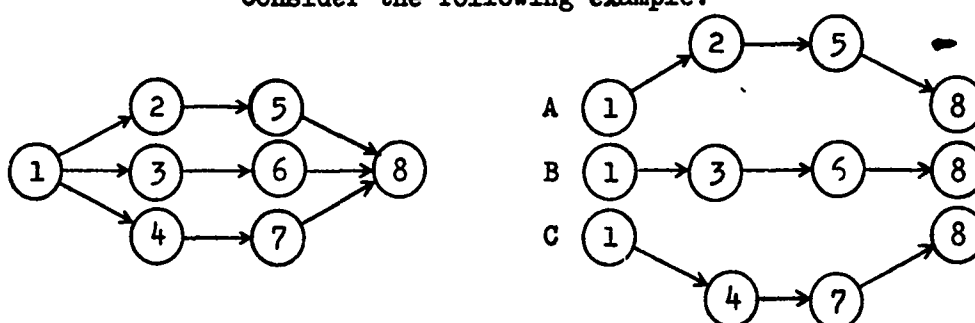


Figure 15. Sample Multipath System.

PATH	A			B			C		
Task	1-2	2-5	5-8	1-3	3-6	6-8	1-4	4-7	7-8
p_u	1.0	.70	.80	.90	.50	.85	.70	.98	.90
p_t	1.0	.95	1.0	.95	.90	.98	.98	1.0	.95
t_u	15	30	15	17	30	18	10	10	10
t_t	5	25	12	12	20	12	8	8	8
p_t/p_u	1.000	1.357	1.250	1.056	1.800	1.153	1.400	1.020	1.056
Δt	10	5	3	5	10	6	2	2	2
Σt_{iu}	60			65			30		

* These data are not related to the Tracer System. They are presented for exposition of this point only.

NAVTRADEVCEEN 1218-4

Note that:

- 1) Path B is the CSTP with a Σt_{iu} of 65 seconds.
- 2) The difference between Path B and Path A is 5 seconds.

In computing the FOM for task 1-3, the formula is applied:

$$FOM = \left[\frac{p_t/p_u \Sigma t_{iu}}{\Sigma t_{iu} - \Delta t} - 1 \right] \times 100 = \left[\frac{1.055(65)}{60} - 1 \right] \times 100$$

However, in computing the FOM for task 3-6, it is noted that the $\Delta t = 10$ is greater than the 5 seconds difference between Path A and Path B. Thus:

$$FOM = \left[\frac{p_t/p_u \Sigma t_{iu}}{\Sigma t_{iu} - \Delta t} - 1 \right] \times 100 = \left[\frac{1.800(65)}{60} - 1 \right] \times 100$$

In the denominator, the value of $\Sigma t_{iu} - \Delta t$ is given as 60, although theoretically $\Sigma t_{iu} - \Delta t$ appears to be 65 - 10, or 55. The denominator of this expression represents system operating time after training on task 3-6.

We may expect that Path B will be completed in 55 seconds after training on task 3-6 but system operating time will still be 60 seconds--determined by Path A which would be the longest path, if we trained task 3-6.

Similarly, in computing the FOM for task 6-8, we apply the formula:

$$FOM = \left[\frac{1.153(65)}{60} - 1 \right] \times 100$$

We can only realize 5 seconds of the 6 seconds improvement in system performance in task 6-8 with training. It may be said then that Path A places a "bound" on the improvement in system performance that may be expected from training on tasks in Path B.

Therefore, the analyst should be constantly aware of the bounds imposed by other paths on FOM's computed in the CSTP.

Common Tasks in the Presence of a Bound--When the situation described above occurs and non-CSTP's impose limitations on the FOM's for certain tasks, one condition can free the path of this limitation. If the task in question is common to both the CSTP and the bounding path, the limitation does not apply. Since training on the common task will result in a subsequent decrease in both path times (to the extent of Δt), the bound really does not exist for that task. Thus, in each case, the analyst should first check for the presence of a limiting path time and, if it exists, check for the commonality of that task to both paths. If the task is common to both the CSTP and the limiting path, the bound does not apply. If the task is not common to both paths, the limit is imposed as described above.

Identical Path Times--When a situation arises in which two paths have an identical Σt_{iu} and both are the CSTP, the tasks in both paths are pooled and treated as a single CSTP. $FOM_{T\&A}$ is used for tasks in both paths. In this case, the next nearest path time acts as the bound on the FOM's computed in both paths.

Tracer System - FOM's--All FOM's are entered on line 8 in the iteration table (see Table 7). FOM's are computed in Path A first (the CSTP) using the formula for $FOM_{T\&A}$ (3). Note that task 12-13 is a repetitive task for which the FOM is 1.7%. FOM's are expressed in the table as percent improvement. Training on task 13-14 would yield 4% improvement in system performance, task 14-15 would yield 30% and task 16-18 would yield 44%.

Note that in this example, Path B does not impose a bound on any of the FOM's in Path A.

Cost Entries--When all FOM's have been computed and entered in the table, the cost data are entered. The total costs per tasks as computed in the cost table (expressed in thousands of dollars) are entered on line 9 for each task.

Double Entry--After computing the FOM's for tasks in Path A, the next step is to enter the CSTP FOM's for all tasks in the CSTP that lie on other paths as well. In the example, 12-13, 13-14, and 14-15 are all common to the CSTP and Path B. Their CSTP FOM's are carried into the appropriate Path B cells (see Table 7).

After carrying CSTP FOM's into common task cells, the FOM's are computed and entered for non-common, non-CSTP tasks. In the example, task 17-19 (noted as NC, at the head of the column) is the only non-common, non-CSTP task.

Computation of FOM/Cost Ratio--On any given iteration, the aim is to determine the single task which offers the greatest benefit to system performance per training dollar. This is the task which offers the greatest "payoff" per dollar invested. Payoff, in these terms, is represented by the FOM-to-cost ratio. Thus, the next step is to compute the FOM/cost ratio for each task. These ratios are entered on line 10 of the table.

Again, it will be found useful to perform these computations in the CSTP first, then transcribe the CSTP ratios to all common tasks, and, last, to compute and enter the ratios for all the rest.

Selection of the Task for Training--As noted above, the task selected for training on any iteration is the task with the highest FOM/cost ratio. This rule is applied regardless of the path on which the

task lies. The highest ratio indicates the task on which training will yield the greatest benefit to system performance per dollar expended, whether that benefit is in terms of both time and accuracy or accuracy alone.

The task to be trained is indicated with an arrowhead or triangle shown in Table 7. This symbol is entered below the task in every path in which the task occurs. In the Tracer System, the first task selected for training is task 16-18 in Path A which has the highest ratio, .799. Note that this task is not common to Path B.

. Iteration II

Determination of New Σt_{iu} --After the task with the highest payoff in terms of FOM/cost ratio has been selected, it remains to examine the implications for the system if that task were to be trained. The first determination to make is whether there is a change in path time, and whether the task selected lies on the CSTEP.

The task selected in the first iteration is removed from further consideration and a new Σt_{iu} is computed. Obviously, this is accomplished quite simply by subtracting the Δt for the task selected from the previous Σt_{iu} . The Σt_{iu} is computed for each path. In the Tracer System (see Table 7) since task 16-18 has a Δt of 12 seconds, the path time for A is reduced to 49 seconds, while Path B remains the same. It is important to recognize that, had 16-18 been common to A and B, B would also have been reduced by 12 seconds.

Again, the path with the longest time, the greatest Σt_{iu} , is the critical path, the CSTEP. The critical path may be the same as in the first iteration or it may change, depending upon the task selected for training.

NAVTRADEVGEN 1218-4

Computation of the FOM--The next step in the second iteration is to compute the FOM for each task. The procedures used in Iteration I apply. However, some rules of thumb may be noted:

- a. If the task selected in the previous iteration is a non-CSTP task, the balance of the FOM's remain the same.
- b. If the task selected in the previous iteration is a CSTP task but the Δt for that task is zero (no time gained), the balance of FOM's remain the same.
- c. If the task selected in the previous iteration is a CSTP task and the Δt for that task is greater than zero (a time gain was realized), recompute these FOM's involving time on the CSTP.

As before, compute the FOM's in the CSTP first, then transcribe the common task FOM's to non-CSTP's, and, last, compute the FOM's for the remaining tasks.

Cost Changes--A major effect to examine in each succeeding iteration is the change in total costs per task as a result of "buying the equipment" for the previous tasks. The cost table originally prepared was constructed in the format shown, expressly to facilitate the recognition of such changes from iteration to iteration. Here the reader is referred to the cost table shown on page 149.

The first step in the determination of cost changes is to indicate in the cost table the task selected for training in the previous iteration. Each remaining task is now examined against the cost table. The question to be answered in each case is, "Does this task have any equipment in common with tasks already selected for

training?" If common equipments exist, the total cost for the task in question is reduced by the cost of the common equipment (equipment which, in a sense, has already been "bought").

In the Tracer System, note that training task 16-18 involves "buying" an XYZ-99 radar, a DC #4 setup simulator, and a Type I power supply. Further note that all other tasks utilize an XYZ-99 radar and a Type I power supply. In the second iteration then, all remaining task costs were reduced by \$52,000, the cost of these two units (see line 13, Table 7).

Obviously, this can have a significant effect on subsequent FOM/cost ratios. Note, for example, that in the second iteration of the Tracer System task 14-15 is selected for training. Task 12-13 has identical equipment requirements with task 14-15. Therefore, on the next iteration the costs for task 12-13 are zero, and the ratio is infinity.

Computation of the FOM/Cost Ratio--Having entered new FOM's and new costs, the next step is to compute new FOM/cost ratios. These ratios will determine the task with the next greatest "payoff," the next task to be selected for training. Again, the task with the highest ratio, regardless of path, is selected for training. In this connection, note that when costs are reduced to zero, as described above, the resulting FOM/cost ratios will be infinity. These tasks take precedence for selection over any other tasks, since they give us "something for nothing."

5. Table of Results

The iterative procedure is continued until all tasks have been selected and removed from consideration. Results for fixed sequence systems may be plotted in the same manner as for rate systems.

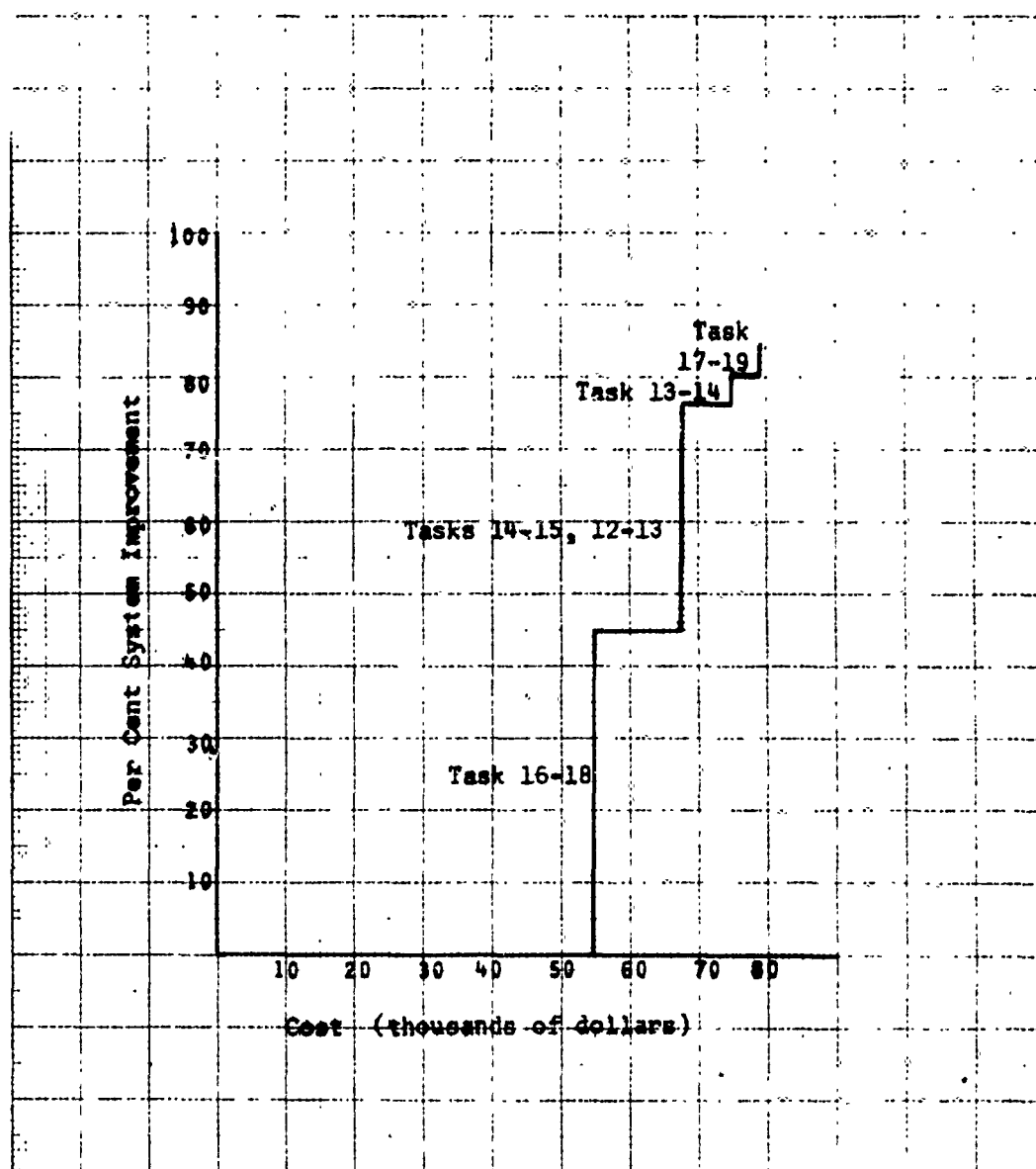
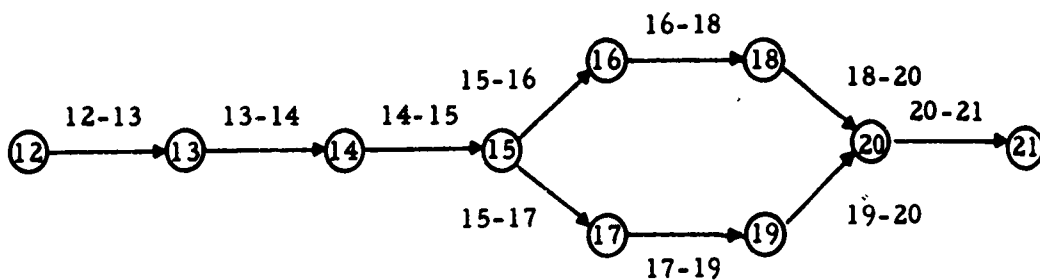
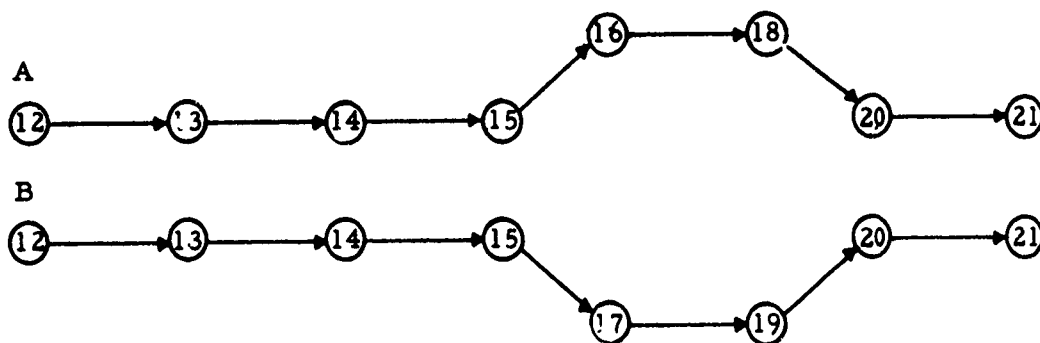


Figure 16. Tracer System--System Improvement as a Function of Cost

Network



Paths



Computation of "K"

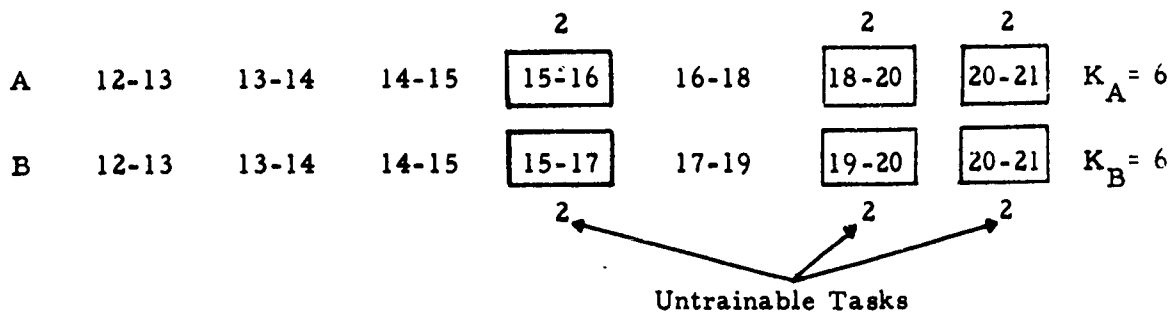


Figure 17.

Network - Paths - Computation of "K"

Table 7

Tracer System Iteration Table

		R		A		R		B		NC
		1213	1314	1415	1618	1213	1314	1415	1719	
line 1		P_u	.85, 1.0	.95	.75	.85	.85, 1.0	.95	.75	.95
line 2		P_t	.95, 1.0	.99	.98	.99	.95, 1.0	.99	.98	.99
line 3		t_u	7	6	12	30	6, 7	6	12	10
line 4		t_t	6	6	12	18	6, 6	6	12	5
line 5		P_t/P_u	1	1.04	1.30	1.16	1	1.04	1.30	1.04
line 6		Δt	1	0	0	12	1	0	0	5
line 7		Σt_{iu}		(61)				(41)		
Iteration 1	line 8	FOM	1.7	4	30	44	1.7	4	30	4
	line 9	COST	60	66	66	55.1	60	66	66	72
	line 10	FOM/COST	.028	.061	.455	.799	.028	.061	.455	.050
	line 11	Σt_{iu}		(49)		▲		(41)		
Iteration 2	line 12	FOM	2	4	30		2	4	30	4
	line 13	COST	8	14	14		8	14	14	20
	line 14	FOM/COST	.250	.286	2.143		.250	.286	2.143	.200
	line 15	Σt_{iu}		(49)	▲			(41)	▲	
Iteration 3	line 16	FOM	2	4			2	4		4
	line 17	COST	6	6			6	6		12
	line 18	FOM/COST	.67	.67			.67	.67		.33
	line 19	Σt_{iu}	▲	(48)			▲	(40)		
Iteration 4	line 20	FOM		4				4		4
	line 21	COST		6				6		12
	line 22	FOM/COST		.67				.67		.33
	line 23	Σt_u		▲				▲		
Iteration 5	line 24	FOM								4
	line 25	COST								4
	line 26	FOM/COST								1.00
	line 27	Σt_{iu}		(48)				(35)		▲

F. Mixed Systems - Procedures

The majority of the systems that will be analyzed by TAP will be mixed systems. Mixed systems are fundamentally rate-type systems which include one or more fixed-sequence segments. As is true for all rate-type systems, there is in the mixed system a limiting element (or entity) which determines the rate at which the system can cycle. In the treatment of pure rate systems, this limiting element was called the "bottleneck task." The FOM's for the bottleneck task were computed by the rate and accuracy formula. The appropriate formula for the remaining task FOM's was an accuracy-only formula.

The limiting entity in a mixed system is called the "critical entity" rather than the bottleneck task because, although the rate-type unit with the slowest rate may be a rate-type task, the slowest entity is more often the Critical System Time Path (CSTP) of a fixed-sequence segment of the mixed system. A fixed-sequence segment of a mixed system is treated like a rate-type task in identifying the critical entity because, while all of the tasks within the sequence are rigidly bound together in terms of the order of their performance, the sequence itself may be repeated at any time after it is completed.

The purpose of identifying the critical entity is to determine the appropriate FOM formula for each task. If the longest path through a fixed-sequence segment (the CSTP) in a mixed system takes more time (has a slower rate) than the CSTP of any other fixed sequence, and more than any rate-type task in the system, then the tasks along that CSTP take the rate and accuracy FOM formula and the FOM's for all other tasks in the system are calculated by the accuracy-only formula. If a rate-type task has the slowest rate (takes the longest time), then only that task takes the rate and accuracy FOM formula. All others take the accuracy-only formula.

The general steps outlined for both fixed sequence and rate systems apply to mixed systems as well. These include diagramming the system,

recording performance estimates in a task table and cost estimates in a cost table, and performing the necessary iterations. The analyst who has carefully followed the preceding explanation of procedures for handling rate and fixed sequence systems should have very little difficulty in performing TAP on mixed systems. A checklist designed to assist the analysis of mixed systems appears in **Appendix C**.

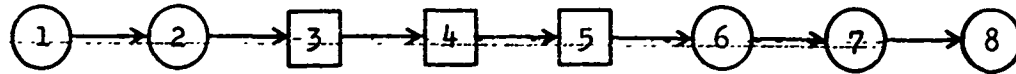
The material below is presented to guide the analyst through some of the more unusual or unique situations which may arise in the analysis of mixed systems.

1. Linked Fixed Sequences

Before computing FOM's, using the iteration table, the analyst must determine the system entity which limits the rate at which the system may cycle (i.e., the critical entity). This is the only system entity in which an improvement in task rate can result in an improvement in system rate. Therefore, the only tasks which take the rate and accuracy FOM formula are the ones in the critical entity. A critical entity may be a rate-type task or the CSTP of a fixed sequence. However, there are occasions when two fixed sequences must be considered as a single fixed sequence. This is true when a terminal fixed sequence of a system is linked to an initial fixed sequence, in the sense that the initial fixed sequence cannot be repeated until the terminal one is completed.

If a mixed system begins and ends with a fixed sequence, and if the system cannot recycle until the last system task is completed, the initial and terminal fixed sequences are considered "linked" and must be treated together as a single unit in identifying the critical entity of the system. If the combined fixed sequence is found to be the critical entity, it must also be treated together in computing the rate ratio of the FOM formula.

The reasons behind this method of handling linked fixed sequences may best be illustrated by example. Consider the following system:

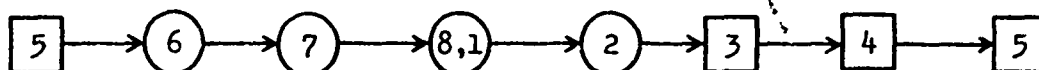


This system has two fixed sequences (1-2, 2-3, and 5-6, 6-7, 7-8) separated by two rate-type tasks. If there were some tasks in a buoy-setting system that could be repeated while other tasks in the cycle were going on, it might look like this example. Let us say that Event 1 in this system is a signal from a deck officer to the bridge, saying that the deck has been secured for steaming to a new location and Task 1-2 is "steam to location." The characteristic of this system which makes it of interest is that Event 1 is the same as Event 8. Task 1-2 cannot be performed a second time until Task 7-8 is finished. The ship cannot "steam to location" (Task 1-2) until "securing the deck" (Task 7-8) has been completed.

In undertaking TAP for this system, we want to identify the critical entity, compute FOM for each task using the appropriate formula, and select the first task to be trained. The illustration will be simplified if we assume that potential accuracy improvement through training is uniform over all seven tasks and that training costs are equal. Let us further assume that, in the present system, Task 3-4 has the slowest rate before training and the greatest potential proportional gain in rate to be derived from training, when compared with the two fixed sequences and the other rate-type task. Under these assumptions, and following the usual procedures, Task 3-4 would have the largest FOM, and we would decide to train Task 3-4 first.

This decision would be incorrect if the untrained rate for Task 3-4 were greater (if it were faster) than the combined rate of the two fixed sequences. If Task 3-4 were faster than the combined fixed sequence rate, even though it were not faster than either fixed sequence taken

separately, the outputs of this task would have to queue up as the system went through multiple cycles. The combined fixed sequence would be the bottleneck or critical entity, and any improvement in the rate of Task 3-4 would not be reflected in improvement in the system operating rate. Task 3-4 should have been considered the critical entity, and its rate estimates should have been included in its FOM, only if its untrained rate had been slower than the sequence: 5-6, 6-7, 7-8, 1-2, 2-3. If it helps to clarify this argument, the system may be redrawn as below:



In summary, there are two points to be made about linked fixed sequences:

1. They must be considered together in identifying the critical entity of the system.

2. If the linked fixed sequences turn out to be the critical entity of the system, all of the tasks in the combined CSTP must be used in calculating the rate ratio $\frac{r_{it}}{r_{iu}}$ in the FOM formula.

2. Tasks Considered in Computing the Rate Ratio

When working with mixed systems, analysts may occasionally have some difficulty in determining the task time estimates to be used in computing the rate ratio in the FOM formula for rate and accuracy (Formula 1).

$$FOM_{R\&A} = \left[\frac{p_{it}}{p_{iu}} \cdot \frac{r_{it}}{r_{iu}} - 1 \right] \times 100 \quad (1)$$

In analyzing pure rate systems, analysts have no difficulty in using only the rate and accuracy estimates for the bottleneck task. Similarly, in analyzing pure fixed sequence systems, analysts have no difficulty in

realizing that task accuracy estimates and system time estimates must be used in the time and accuracy FOM formula for tasks along the CSTP.

But when they come to mixed systems and find that the rate and accuracy formula must sometimes be applied to a rate-type task and sometimes to a CSTP, they may become confused. The correct rate estimates to use in Formula 1 are as follows:

When the critical entity is a rate-type task:

r_{it} = The reciprocal of the trained time estimate for that task.

and: r_{iu} = The reciprocal of the untrained time estimate for that task.

When the critical entity is a CSTP:

$r_{it} = \frac{1}{t_{it} + t_{1u} + t_{2u} + \dots + t_{nu}}$ (the CSTP rate when the ith task in the sequence is trained)

$r_{iu} = \frac{1}{\Sigma t_{iu}}$ (the rate of the CSTP when none of the tasks are trained)

where: t_{it} = The trained time estimate for the ith task.

$t_{1u} \dots t_{nu}$ = The untrained time estimates for all tasks in the CSTP other than the ith task.

Σt_{iu} = The estimated untrained time for the CSTP.

3. Repetitive Sequences of Tasks

Repetitive tasks have been discussed and the method for handling them has been explained. However, it has not been mentioned that a mixed

system may have a fixed sequence of tasks where the sequence itself is repetitive.* It is also possible to encounter a repetitive fixed sequence within a nonrepetitive fixed sequence. When a sequence is repetitive, this means that the final task has an output which must be within acceptable limits before the system can proceed with its cycle. Whenever the output is not acceptable, the sequence of tasks leading to that output must be repeated until an acceptable output is produced.

The procedure for handling repetitive sequences of tasks is similar to the procedure for handling repetitive tasks, which has been explained and illustrated in considering the fixed-sequence Tracer System Network. It is necessary to substitute expected time estimates wherever simple trained and untrained time estimates are normally used.

The time required to complete the repetitive sequence once is the summation of individual task times. The probability that the sequence is completed successfully on a single sequence cycle is the product of the individual task probabilities. On the first iteration for the repetitive sequence, the expected untrained time is:

$$t'_{iu} = \frac{\sum t_{iu}}{\pi p_{iu}}$$

where: $\sum t_{iu}$ = The sum of the untrained time estimates for all tasks in the repetitive sequence.

πp_{iu} = The product of the untrained probability of success per given attempt for all tasks in the repetitive sequence.

If the second task of a three-task repetitive sequence is taken, as trained, the expected time for the sequence becomes:

* This possibility also exists in pure fixed sequence systems.

$$t'_{2t} = \frac{t_{1u} + t_{2t} + t_{3u}}{(p_{1u})(p_{2t})(p_{3u})}$$

If this three-task repetitive sequence is the critical entity of a mixed system, the FOM for the second task in the sequence would be computed by the formula:

$$FOM_{R\&A} = \left[\frac{p_{2t}}{p_{2u}} \cdot \frac{r_{2t}}{r_{2u}} - 1 \right] \times 100$$

where: $\frac{p_{2t}}{p_{2u}}$ = The ratio of the trained and untrained probabilities that task 2 will be completed successfully, or 1.0.

$$r_{2t} = \frac{1}{t'_{2t}}$$

$$r_{2u} = \frac{1}{t'_{iu}}$$

4. Negative FOM's

The FOM is, by definition, the estimated percentage system improvement as a result of training. The implication in previous discussions is that FOM's must always be positive. This is not necessarily the case. There will be situations in which training results in an increase in time-to-perform a task rather than a decrease.

For example, it was found that a task of sonar classification is performed rather hastily by untrained operators. This results in a low probability of success but also in an unrealistically low time-to-perform compared to trained operators. Trained operators utilize more cues in the situation and make judgments with greater care. Performance

estimates for trained operators, then, have considerably higher probabilities of success--but longer times-to-perform.

The computation of FOM for tasks in a rate-type system utilizes the following formula:

$$FOM_{R\&A} = \left[\frac{p_t}{p_u} \cdot \frac{r_t}{r_u} - 1 \right] \times 100 \quad (1)$$

Consider a task for which performance estimates are:

$$p_u = .3, \quad p_t = .6, \quad t_u = 10 \text{ secs.}, \quad t_t = 30 \text{ secs.}$$

Using $r = \frac{1}{t}$, rates for this task are: $r_u = 6/\text{minute}$ and $r_t = 2/\text{minute}$. Applying these figures to formula (1):

$$FOM_{R\&A} = \left[\frac{.6}{.3} \cdot \frac{2}{6} - 1 \right] \times 100$$

$$FOM_{R\&A} = -33$$

The FOM resulting from these figures is negative. This says, in effect, that there is not an improvement in system performance but a decrement, as a result of training. This is reasonable when one considers that while there is a 100% improvement in accuracy of performance on the task (from .3 to .6), there is a threefold loss in time. Thus, on a purely mathematical basis, the decrement in time outweighs the improvement in accuracy. The FOM is still a legitimate statement of task contribution to system performance through training.

Caution should be observed in situations which result in negative FOM's. Considerable care must be taken to insure that trained and untrained performance estimates refer to the same task. The general statement has been made that "untrained operators perform hurriedly--

without necessary care." In the strict sense, if the operator does not perform all the necessary steps in a task and actually performs a reduced version of the task as compared with that performed by the trained operator, then the tasks are different. The reduction in the number of steps performed might well account for the difference in time between trained and untrained performance. It is incumbent upon the analyst, therefore, to define precisely the task in question and insure that performance estimates relate to the same behavioral unit.

APPENDIX A

RATE SYSTEM PROCEDURES CHECKLIST

1. Network

- a. From task analysis, identify tasks and task sequences.
- b. Multiple missions? Separate networks necessary?
- c. Develop network(s).

2. Task Table

- a. List all tasks.
- b. Indicate repetitive tasks.
- c. Record estimate of probability of accurate performance, trained and untrained, for each non-repetitive task. Record estimate of probability of success per given attempt, trained and untrained, for each repetitive task.
- d. Record estimate of performance time, trained and untrained, for each non-repetitive task. Record estimate of time per given attempt, trained and untrained, for each repetitive task.
- e. Compute rate of performance (or expected rate of performance), trained and untrained, for each task.

3. Cost Table

- a. List trainable tasks.
- b. List equipment required per task.

- c. Determine number of copies planned for procurement.
- d. Obtain cost data--note fixed and variable costs. Obtain the same set of supplementary costs for each task.
- e. Determine total cost per task.

4. Iteration Table

- a. List in columns only the trainable tasks.
- b. Indicate repetitive tasks.
- c. Enter trained and untrained: time, expected time, probability, rate, and expected rate estimates.
- d. Compute p_{it}/p_{iu} for each task.
- e. Compute r_{it}/r_{iu} or r'_{it}/r'_{iu} for each task.
- f. Identify the critical (bottleneck) task.

Iteration I

- (a) Compute FOM for critical task first, using model for improvements in both rate and accuracy (considering bounds imposed by other noncritical tasks).
- (b) Compute FOM's for remaining noncritical tasks using model for improvement in accuracy only.
- (c) Enter costs from cost table.
- (d) Compute FOM/cost ratio for each task.

NAVTRADEVCEEN 1218-4

- (e) Select task with the highest ratio for training. This may be any task in the system. If any zero-cost tasks exist, they are also picked up on the first iteration.
- (f) Indicate the selected task(s) in the cost table and in the iteration table.
- (g) Identify critical task. Has it changed?

Iteration II

- (a) Compute FOM for the critical task first; then for non-critical tasks.
- (b) Examine costs for remaining tasks, considering:
 - . Common equipment requirements.
 - . Consequent cost reductions as a result of common equipment requirements.
- (c) Enter new costs for each task.
- (d) Compute FOM/cost ratio for each task.
- (e) Select task with highest ratio for training.
 - . If the cost for any tasks go to zero as a result of identical equipment requirements, the FOM/cost ratios for those tasks go to infinity, and they are selected on the next iteration as having the highest ratio.

Successive Iterations

Continue iterations until all tasks have been selected for training.

5. Results

Plot system improvement against cost in the form of a step function. Each point on the plot represents a task or group of tasks selected at a given expenditure and system improvement.

APPENDIX B

FIXED SEQUENCE SYSTEM PROCEDURES CHECKLIST

1. Network

- a. From task analysis, identify tasks and task sequences.
- b. Multiple missions? Separate networks necessary?
- c. Develop network(s).

2. Task Table

- a. List all tasks.
- b. Indicate repetitive tasks. Indicate repetitive sequences of tasks. (See page 171 for methods of treating repetitive sequences of tasks.)
- c. Record estimate of probability of accurate performance, trained and untrained, for each non-repetitive task. Record estimate of probability of success per given attempt, trained and untrained, for each repetitive task.
- d. Record estimate of performance time, trained and untrained, for each non-repetitive task. Record estimate of time per given attempt, trained and untrained, for each repetitive task.

3. Cost Table

- a. List trainable tasks.
- b. List equipment required per task.

NAVTRADEVCEEN 1218-4

- c. Determine number of copies planned for procurement.
- d. Obtain cost data--note fixed and variable costs. Obtain the same set of supplementary costs for each task.
- e. Determine total cost per task.

4. Iteration Table

- a. List in columns only the trainable tasks.
- b. Indicate repetitive tasks.
- c. Enter trained and untrained: time, expected time, and probability estimates.
- d. Compute Δt or $\Delta t'$ for each task.
- e. Compute p_{it}/p_{iu} for each task.
- f. Determine K for each path (Σt_{iu} for untrainable tasks).
- g. Compute Σt_{iu} for each path (Σt_{iu} for trainable tasks + K).
- h. Determine the Critical System Time Path (CSTP)

Iteration I

- (a) Enter Σt_{iu} for each path of the fixed sequence.
- (b) Compute FOM for each task on the CSTP, using T&A formula (3a). Remember that $t_{iu} - \Delta t$ in this formula cannot fall below the untrained time for any non-CSTP path.

NAVTRADEVCEEN 1218-4

- (c) For those tasks which the CSTP has in common with non-CSTP paths, transcribe the CSTP FOM's.
- (d) Compute FOM's for remaining tasks in the system, using formula (2).
- (e) Enter costs from cost table.
- (f) Compute FOM/cost ratio for each task.
- (g) Select task with the highest ratio for training. This may be any task in the system. If any zero-cost tasks exist, they are also picked up on the first iteration.
- (h) Indicate the selected task(s) in the cost table and in the iteration table.
- (i) Recompute Σt_{iu} for each path in the fixed sequence. Remember that Σt_{iu} includes untrainable tasks.
- (j) Determine whether CSTP has changed.

Iteration II

- (a) Compute FOM for each task on the CSTP.
 - . If task selected in previous iteration was a non-CSTP task, FOM remains the same.
 - . If task selected in previous iteration was a CSTP task and its Δt was zero, FOM remains the same.
 - . If task selected in previous iteration was a CSTP task and its Δt was greater than zero, recompute the FOM.

NAVTRADEVCEEN 1218-4

- (b) Transcribe CSTP FOM's for common tasks to non-CSTP paths.
- (c) Compute non-common, non-CSTP FOM's.
- (d) Examine costs for remaining tasks, considering:
 - . Common equipment requirements with task previously selected.
 - . Cost reductions as a consequence of common equipment requirements.
- (e) Enter new cost for each task.
- (f) Compute FOM/cost ratio for each task.
- (g) Select task with highest ratio for training, regardless of path.
 - . If the cost for any tasks go to zero as a result of identical equipment requirements, the FOM/cost ratios for those tasks go to infinity and they are selected on the next iteration as having the highest ratio.

Successive Iterations

Continue iterations until all tasks have been selected for training.

5. Results

Plot system improvement against cost in the form of a step function. Each point on the plot represents a task or group of tasks selected at a given expenditure and system improvement.

APPENDIX C

MIXED SYSTEM PROCEDURES CHECKLIST

1. Network

- a. From task analysis, identify tasks and task sequences.
- b. Identify relationships among tasks. Rate and fixed sequence.
- c. Multiple missions? Separate networks necessary?
- d. Develop network(s).

2. Task Table

- a. List all tasks.
- b. Indicate which tasks are rate-type and which are part of a fixed sequence.
- c. Indicate repetitive tasks. Indicate repetitive sequences of tasks. (See page 171 for methods of treating repetitive sequences of tasks.)
- d. Record estimate of probability of accurate performance, trained and untrained, for each non-repetitive task. Record estimate of probability of success per given attempt, trained and untrained, for each repetitive task.
- e. Record estimate of performance time, trained and untrained, for each non-repetitive task. Record estimate of time per given attempt, trained and untrained, for each repetitive task.
- f. Compute rate of performance (or expected rate of performance), trained and untrained, for each rate-type task.

NAVTRADEVCEEN 1218-4

- g. Compute expected time to perform for each repetitive task in the fixed sequence(s).
- h. Compute Σt_{iu} for each path in every fixed-sequence segment of the system (include both trainable and untrainable tasks). Record these values separately.

3. Cost Table

- a. List trainable tasks.
- b. List equipment required per task.
- c. Determine number of copies planned for procurement.
- d. Obtain cost data--note fixed and variable costs. Obtain the same set of supplementary costs for each task.
- e. Determine total cost per task.

4. Iteration Table

- a. List in columns only the trainable tasks.
- b. Indicate repetitive tasks.
- c. Enter trained and untrained: time, expected time, probability, rate and expected rate estimates.
- d. Compute p_{it}/p_{iu} for each task.
- e. Compute Δt or $\Delta t'$ for each task in a fixed sequence.
- f. Compute r_{it}/r_{iu} or r'_{it}/r'_{iu} for each rate-type task.

g. Identify the critical entity of the system.

- (1) Consider each fixed sequence, and each task not in a fixed sequence, as a separate entity.
- (2) If a system begins and ends with a fixed sequence, and if the first sequence cannot be repeated before the last sequence is completed, consider these two sequences together as a single entity.
- (3) Each fixed sequence which is considered as an entity will have a CSTP. For every CSTP in the system, compute $r_{u \text{ seq}}$, using formula (4).
- (4) Compare r_{iu} and $r_{u \text{ seq}}$ values. The critical entity for the system is associated with the lowest such value. The critical entity may be either a rate-type task or the CSTP of a fixed sequence.

Iteration I - If the critical entity is the CSTP of a fixed sequence

- (a) Enter Σt_{iu} for each path of the fixed sequence.
- (b) Compute FOM for each task in the critical entity (CSTP), using T&A formula (3a). Remember that $\Sigma t_{iu} - \Delta t$ in this formula cannot fall below the untrained time for any non-critical entity (whether it be a non-critical path in the same fixed sequence, a CSTP in another fixed sequence, or a rate-type task).
- (c) For those tasks which the (critical entity) CSTP has in common with non-CSTP paths in the same fixed sequence, transcribe the CSTP FOM's.

NAVTRADEVCEM 1218-4

- (d) Compute FOM's for remaining tasks in the system, using formula (2).
- (e) Enter costs from cost table.
- (f) Compute FOM/cost ratio for each task.
- (g) Select task with the highest ratio for training. This may be any task in the system. If any zero-cost tasks exist, they are also picked up on the first iteration.
- (h) Indicate the selected task(s) in the cost table and in the iteration table.
- (i) If the task selected for training was part of a fixed sequence, recompute Σt_{iu} for each path in the fixed sequence. Remember that Σt_{iu} includes untrainable tasks.
- (j) If a task selected for training was part of a fixed sequence, determine whether the CSTP for that sequence has been changed.
- (k) Has the critical entity changed?

Iteration I - If the critical entity is a rate-type task

- (a) Compute FOM for the critical entity, using R&A formula (1). Remember that r_{iu} in this formula may not exceed the r_{it} or $r_{u\text{seq}}$ for any non-critical entity.
- (b) Compute FOM's for all remaining tasks, using formula (2).
- (c) Enter costs from cost table.
- (d) Compute FOM/cost ratio for each task.

- (e) Select task with the highest ratio for training. This may be any task in the system. If any zero-cost tasks exist, they are also picked up on the first iteration.
- (f) Indicate the selected task(s) in the cost table and in the iteration table.
- (g) If the task selected for training was part of a fixed sequence, recompute Σt_{iu} for each path in the fixed sequence. Remember that Σt_{iu} includes untrainable tasks.
- (h) If the task selected for training was part of a fixed sequence, determine whether the CSTP for that sequence has been changed.
- (i) Has the critical entity changed?

Subsequent Iterations

Subsequent iterations are handled largely the same as the first, except that, as each task is selected for training, the costs for the remaining tasks must be reevaluated. The factors to consider are:

- (a) Common equipment requirements.
- (b) Consequent cost reductions as a result of common equipment requirements.

5. Results

Plot system improvement against cost in the form of a step function. Each point on the plot represents a task or group of tasks selected at a given expenditure and system improvement.

APPENDIX D
TAP GLOSSARY

Accuracy Estimate: An estimate of the likelihood that a task will be performed to some predetermined level of acceptability.

Bottleneck Task: In rate systems, the task with the slowest rate.

Cost Estimate: An estimate of all hardware costs involved in training a task.

Critical Entity: In a mixed system, that task or set of tasks which limits the rate at which the system can cycle.

Critical System Time Path: In fixed sequence systems, the path with the greatest sum of untrained task time estimates.

CSTP: (See Critical System Time Path.)

Figure of Merit: The percentage system improvement with training.

Fixed Sequence System: A system in which no task in the system can be started until the previous task in the sequence has been completed, and the first task in the system cannot be repeated until the last task has been completed.

FOM: (See Figure of Merit.)

Mixed System: A rate system in which fixed sequences of tasks exist.

Nonrepetitive Task: A task which is only performed once, regardless of the accuracy of performance.

NAVTRADEVCEV 1218-4

Rate System: A system in which all tasks are independent of the system cycle.

Tau: The period of time during which the system is allowed to operate.

Time Estimate: The estimated amount of time taken to perform a task.

Trainable Task: A task for which improvement may be expected with training.

Trained Performance: The level of performance expected after training.

Untrainable Task: A task for which there is no improvement with training.

Untrained Performance: The estimated entering level of performance.

Zero Cost Item: Trainable tasks for which it is determined that hardware is not required for training.

UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R&D		
(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)		
1. ORIGINATING ACTIVITY (Corporate author) Applied Science Associates, Inc. Valencia, Pa.		2a. REPORT SECURITY CLASSIFICATION Unclassified
		2b. GROUP
3. REPORT TITLE GUIDELINES FOR TRAINING SITUATION ANALYSIS (TSA)		
4. DESCRIPTIVE NOTES (Type of report and inclusive dates) Final Report		
5. AUTHOR(S) (Last name, first name, initial) Chenzoff, Andrew P. Folley, John D., Jr.		
6. REPORT DATE July 1965	7a. TOTAL NO. OF PAGES 190	7b. NO. OF REFS
8a. CONTRACT OR GRANT NO. N61339-1218	8a. ORIGINATOR'S REPORT NUMBER(S) Technical Report NAVTRADEVCEEN 1218-4	
b. PROJECT NO. 7568		
c.	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned to this report)	
d.		
10. AVAILABILITY/LIMITATION NOTICES Qualified requesters may obtain copies of this report from DDC.		
11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY U.S. Naval Training Device Center Port Washington, New York 11050	
13. ABSTRACT <p>These guidelines represent a textbook for instruction in three phases of Training Situation Analysis (TSA), a standardized procedure, developed by NTDC, for systematically gathering and interpreting the information which is relevant to the planning of training and training devices.</p> <p>Three phases of TSA are described in detail: System Familiarization, Task Analysis Method (TAM) and Training Analysis Procedure (TAP). System Familiarization provides an orientation to the training problem, the system structure and flow, and the equipment. Task Analysis Method produces a set of task descriptions containing the information necessary for making training device decisions. Training Analysis Procedure produces a ranking of tasks based upon the potential benefit to system performance as a result of training and the cost of that training. Recommendations for the conduct of these three phases and suggested working forms are presented.</p>		

DD FORM 1473
1 JAN 64
(front)Unclassified
Security Classification

UNCLASSIFIED

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Training Task Analysis System Description Training Devices Guides Man-Machine Systems Task Analysis Method (TAM) Training Analysis Procedures (TAP) Training Devices Training Situation Analysis (TSA)						

INSTRUCTIONS

1. **ORIGINATING ACTIVITY:** Enter the name and address of the contractor, subcontractor, grantee, Department of Defense activity or other organization (*corporate author*) issuing the report.

2a. **REPORT SECURITY CLASSIFICATION:** Enter the overall security classification of the report. Indicate whether "Restricted Data" is included. Marking is to be in accordance with appropriate security regulations.

2b. **GROUP:** Automatic downgrading is specified in DoD Directive 5200.10 and Armed Forces Industrial Manual. Enter the group number. Also, when applicable, show that optional markings have been used for Group 3 and Group 4 as authorized.

3. **REPORT TITLE:** Enter the complete report title in all capital letters. Titles in all cases should be unclassified. If a meaningful title cannot be selected without classification, show title classification in all capitals in parenthesis immediately following the title.

4. **DESCRIPTIVE NOTES:** If appropriate, enter the type of report, e.g., interim, progress, summary, annual, or final. Give the inclusive dates when a specific reporting period is covered.

5. **AUTHOR(S):** Enter the name(s) of author(s) as shown on or in the report. Enter last name, first name, middle initial. If military, show rank and branch of service. The name of the principal author is an absolute minimum requirement.

6. **REPORT DATE:** Enter the date of the report as day, month, year, or month, year. If more than one date appears on the report, use date of publication.

7a. **TOTAL NUMBER OF PAGES:** The total page count should follow normal pagination procedures, i.e., enter the number of pages containing information.

7b. **NUMBER OF REFERENCES:** Enter the total number of references cited in the report.

8a. **CONTRACT OR GRANT NUMBER:** If appropriate, enter the applicable number of the contract or grant under which the report was written.

8b, 8c, & 8d. **PROJECT NUMBER:** Enter the appropriate military department identification, such as project number, subproject number, system numbers, task number, etc.

9a. **ORIGINATOR'S REPORT NUMBER(S):** Enter the official report number by which the document will be identified and controlled by the originating activity. This number must be unique to this report.

9b. **OTHER REPORT NUMBER(S):** If the report has been assigned any other report numbers (*either by the originator or by the sponsor*), also enter this number(s).

10. **AVAILABILITY/LIMITATION NOTICES:** Enter any limitations on further dissemination of the report, other than those

imposed by security classification, using standard statements such as:

- (1) "Qualified requesters may obtain copies of this report from DDC."
- (2) "Foreign announcement and dissemination of this report by DDC is not authorized."
- (3) "U. S. Government agencies may obtain copies of this report directly from DDC. Other qualified DDC users shall request through _____."
- (4) "U. S. military agencies may obtain copies of this report directly from DDC. Other qualified users shall request through _____."
- (5) "All distribution of this report is controlled. Qualified DDC users shall request through _____."

If the report has been furnished to the Office of Technical Services, Department of Commerce, for sale to the public, indicate this fact and enter the price, if known.

11. **SUPPLEMENTARY NOTES:** Use for additional explanatory notes.

12. **SPONSORING MILITARY ACTIVITY:** Enter the name of the departmental project office or laboratory sponsoring (*paying for*) the research and development. Include address.

13. **ABSTRACT:** Enter an abstract giving a brief and factual summary of the document indicative of the report, even though it may also appear elsewhere in the body of the technical report. If additional space is required, a continuation sheet shall be attached.

It is highly desirable that the abstract of classified reports be unclassified. Each paragraph of the abstract shall end with an indication of the military security classification of the information in the paragraph, represented as (TS), (S), (C), or (U).

There is no limitation on the length of the abstract. However, the suggested length is from 150 to 225 words.

14. **KEY WORDS:** Key words are technically meaningful terms or short phrases that characterize a report and may be used as index entries for cataloging the report. Key words must be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context. The assignment of links, roles, and weights is optional.

(back)

UNCLASSIFIED

Security Classification

U.S. NAVAL TRAINING DEVICE CENTER Tech. Rept. NAVTRADEVEN 1218-4 July 1965 UNCLASSIFIED	U.S. NAVAL TRAINING DEVICE CENTER Tech. Rept. NAVTRADEVEN 1218-4 July 1965 UNCLASSIFIED	U.S. NAVAL TRAINING DEVICE CENTER Tech. Rept. NAVTRADEVEN 1218-4 July 1965 UNCLASSIFIED	U.S. NAVAL TRAINING DEVICE CENTER Tech. Rept. NAVTRADEVEN 1218-4 July 1965 UNCLASSIFIED
GUIDELINES FOR TRAINING SITUATION ANALYSIS (TSA). Andrew P. Chenzoff, John D. Folley, Jr. Applied Science Associates, Inc., Valencia, Pa. (Contract N61339-1218) vii, 190p., illus., appendices, tables.	GUIDELINES FOR TRAINING SITUATION ANALYSIS (TSA). Andrew P. Chenzoff, John D. Folley, Jr. Applied Science Associates, Inc., Valencia, Pa. (Contract N61339-1218) vii, 190p., illus., appendices, tables.	GUIDELINES FOR TRAINING SITUATION ANALYSIS (TSA). Andrew P. Chenzoff, John D. Folley, Jr. Applied Science Associates, Inc., Valencia, Pa. (Contract N61339-1218) vii, 190p., illus., appendices, tables.	GUIDELINES FOR TRAINING SITUATION ANALYSIS (TSA). Andrew P. Chenzoff, John D. Folley, Jr. Applied Science Associates, Inc., Valencia, Pa. (Contract N61339-1218) vii, 190p., illus., appendices, tables.
These guidelines represent a textbook for instruction in three phases of Training Situation Analysis (TSA), a standardized procedure, developed by NTDC, for systematically gathering and interpreting the information which is relevant to the planning of training and training devices.	These guidelines represent a textbook for instruction in three phases of Training Situation Analysis (TSA), a standardized procedure, developed by NTDC, for systematically gathering and interpreting the information which is relevant to the planning of training and training devices.	These guidelines represent a textbook for instruction in three phases of Training Situation Analysis (TSA), a standardized procedure, developed by NTDC, for systematically gathering and interpreting the information which is relevant to the planning of training and training devices.	These guidelines represent a textbook for instruction in three phases of Training Situation Analysis (TSA), a standardized procedure, developed by NTDC, for systematically gathering and interpreting the information which is relevant to the planning of training and training devices.
Three phases of TSA are described in detail: System Familiarization, Task Analysis Method (TAM) and Training Analysis Procedure (TAP). Systems Familiarization provides an orientation to the training problem, the system structure and flow, and the equipment. Task Analysis Method produces a set of task	Three phases of TSA are described in detail: System Familiarization, Task Analysis Method (TAM) and Training Analysis Procedure (TAP). Systems Familiarization provides an orientation to the training problem, the system structure and flow, and the equipment. Task Analysis Method produces a set of task	Three phases of TSA are described in detail: System Familiarization, Task Analysis Method (TAM) and Training Analysis Procedure (TAP). Systems Familiarization provides an orientation to the training problem, the system structure and flow, and the equipment. Task Analysis Method produces a set of task	Three phases of TSA are described in detail: System Familiarization, Task Analysis Method (TAM) and Training Analysis Procedure (TAP). Systems Familiarization provides an orientation to the training problem, the system structure and flow, and the equipment. Task Analysis Method produces a set of task
<p>Descriptores</p> <p>TRAINING</p> <p>TASK ANALYSIS</p> <p>SYSTEM DESCRIPTION</p> <p>TRAINING DEVICES</p> <p>GUIDES</p> <p>MAN-MACHINE</p> <p>SYSTEMS</p> <p>TASK ANALYSIS METHOD (TAM)</p> <p>TRAINING ANALYSIS PROCEDURES (TAP)</p> <p>TRAINING DEVICES</p> <p>TRAINING SITUATION ANALYSIS (TSA)</p> <p>I. Applied Science Associates, Inc.</p> <p>II. N61339-1218</p>	<p>Descriptores</p> <p>TRAINING</p> <p>TASK ANALYSIS</p> <p>SYSTEM DESCRIPTION</p> <p>TRAINING DEVICES</p> <p>GUIDES</p> <p>MAN-MACHINE</p> <p>SYSTEMS</p> <p>TASK ANALYSIS METHOD (TAM)</p> <p>TRAINING ANALYSIS PROCEDURES (TAP)</p> <p>TRAINING DEVICES</p> <p>TRAINING SITUATION ANALYSIS (TSA)</p> <p>I. Applied Science Associates, Inc.</p> <p>II. N61339-1218</p>	<p>Descriptores</p> <p>TRAINING</p> <p>TASK ANALYSIS</p> <p>SYSTEM DESCRIPTION</p> <p>TRAINING DEVICES</p> <p>GUIDES</p> <p>MAN-MACHINE</p> <p>SYSTEMS</p> <p>TASK ANALYSIS METHOD (TAM)</p> <p>TRAINING ANALYSIS PROCEDURES (TAP)</p> <p>TRAINING DEVICES</p> <p>TRAINING SITUATION ANALYSIS (TSA)</p> <p>I. Applied Science Associates, Inc.</p> <p>II. N61339-1218</p>	<p>Descriptores</p> <p>TRAINING</p> <p>TASK ANALYSIS</p> <p>SYSTEM DESCRIPTION</p> <p>TRAINING DEVICES</p> <p>GUIDES</p> <p>MAN-MACHINE</p> <p>SYSTEMS</p> <p>TASK ANALYSIS METHOD (TAM)</p> <p>TRAINING ANALYSIS PROCEDURES (TAP)</p> <p>TRAINING DEVICES</p> <p>TRAINING SITUATION ANALYSIS (TSA)</p> <p>I. Applied Science Associates, Inc.</p> <p>II. N61339-1218</p>

descriptions containing the information necessary for making training device decisions. Training Analysis Procedure produces a ranking of tasks based upon the potential benefit to system performance as a result of training and the cost of that training. Recommendations for the conduct of these three phases and suggested working forms are presented.

III. Tech. Rept.
NAVTRADEVCEEN 1218-4
IV. Chenzoff,
Andrew P.
V. Folley, John D.,
Jr.

descriptions containing the information necessary for making training device decisions. Training Analysis Procedure produces a ranking of tasks based upon the potential benefit to system performance as a result of training and the cost of that training. Recommendations for the conduct of these three phases and suggested working forms are presented.

III. Tech. Rept.
NAVTRADEVCEEN 1218-4
IV. Chenzoff,
Andrew P.
V. Folley, John D.,
Jr.

descriptions containing the information necessary for making training device decisions. Training Analysis Procedure produces a ranking of tasks based upon the potential benefit to system performance as a result of training and the cost of that training. Recommendations for the conduct of these three phases and suggested working forms are presented.

III. Tech. Rept.
NAVTRADEVCEEN 1218-4
IV. Chenzoff,
Andrew P.
V. Folley, John D.,
Jr.

descriptions containing the information necessary for making training device decisions. Training Analysis Procedure produces a ranking of tasks based upon the potential benefit to system performance as a result of training and the cost of that training. Recommendations for the conduct of these three phases and suggested working forms are presented.

III. Tech. Rept.
NAVTRADEVCEEN 1218-4
IV. Chenzoff,
Andrew P.
V. Folley, John D.,
Jr.